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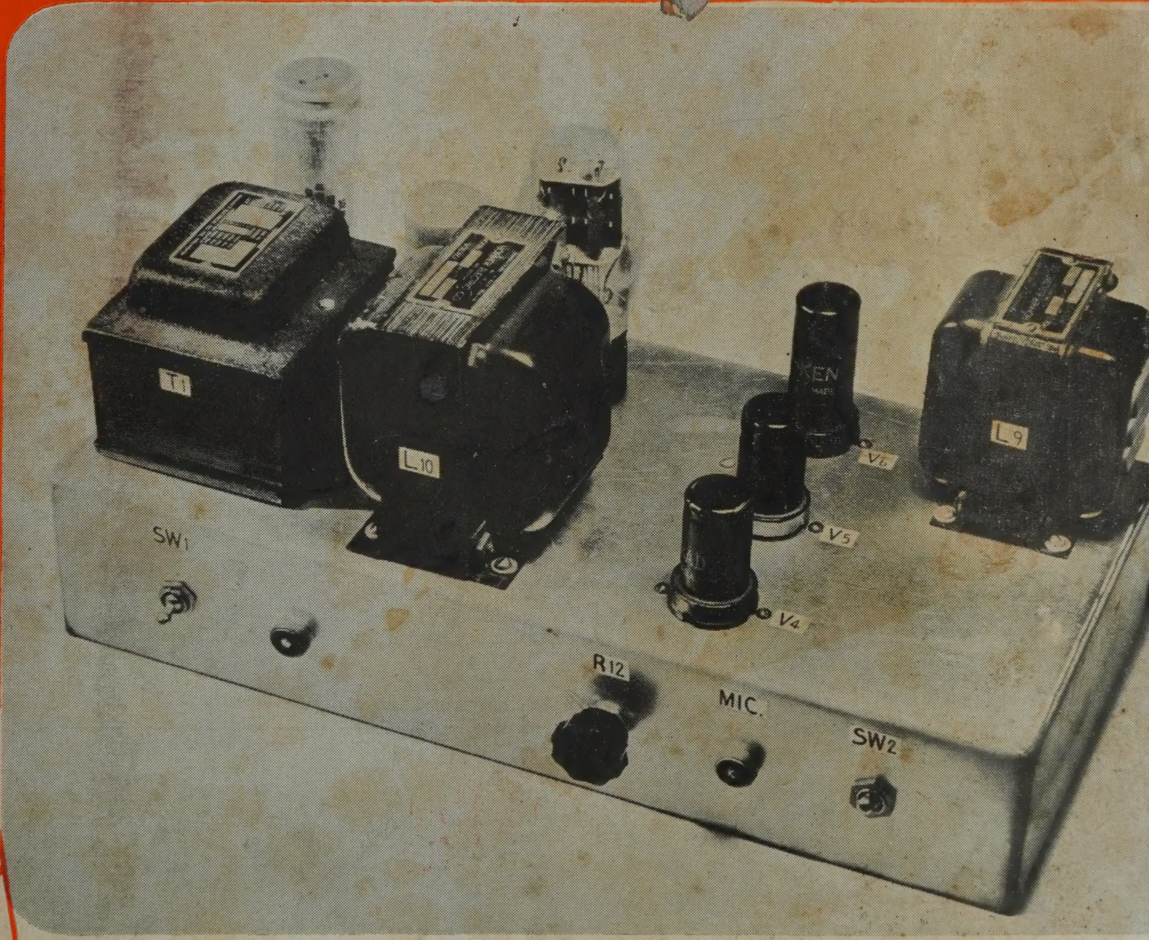

THE RADEL QRP TRANSMITTER
THE SYNCHRODYNE
TUBE DATA—THE EL37
ELECTRONIC MUSIC
PRACTICAL ANALYSIS OF TRANSMISSION LINES, ETC.

SEPTEMBER 1, 1947

1/10


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RADIO and ELECTRONICS

Vol. 2, No. 6 September 1st, 1947

Contents Page

OUR COVER

THIS MONTH the photograph illustrates the modulator and power supply section of the Radel QRP Transmitter. whose description is commenced in this issue, with the details of the R.F. end. Next month the modulator and power supply, together with the operation of the transmitter, will be dealt with.

CORRESPONDENCE

All correspondence, contributions, and enquiries referring to advertising space and rates should be addressed to:—

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NEW ZEALAND AND ATOMIC ENERGY

It was recently reported in the daily press that this country is likely, in the not-too-distant future, to be the proud possessor of a low-energy atomic pile. The fact elicited much editorial comment, and even a few cartoons at the time, the reactions varying between mild astonishment and frank amusement. The pile, it was stated, would not be capable of producing the materials for a kind of home-made atomic bomb, but would give scientific workers in this country a much-needed basis for acquiring a knowledge of nuclear physics in general—knowledge based on practical experience, and far greater in scope than can be obtained from text-books alone.

The products of the pile would be radioactive isotopes, impossible to make by other means, and of much potential value in such diverse fields as medicine and plant research.

One of the most important aspects of the decision to build an atomic pile in this country is that it shows a very live attitude on the part of both the Department of Scientific and Industrial Research and the Government. Whether we like it or not, and whatever our personal views on the danger attaching to the warlike application of nuclear physics, atomic energy is destined to play an increasingly important part in everyday life. This fact has been given official recognition at a comparatively early date, when many of our most capable physicists are still working on atomic energy projects overseas, and when the necessity has become apparent of providing both for keeping New Zealand in the forefront as regards peace-time applications, and for a potential training ground for young scientific workers.

It so happened, during the last war, that this country was able to make notable contributions to the allied cause in the fields of radio and radar design and production, to the surprise of many, who regarded us as a purely agricultural country.

This latest project, however, need occasion no surprise, for the quality of our scientific workers has now been impressed upon the public as never before, and no country, however small, can afford to neglect the literally earth-shaking developments which must be pending.

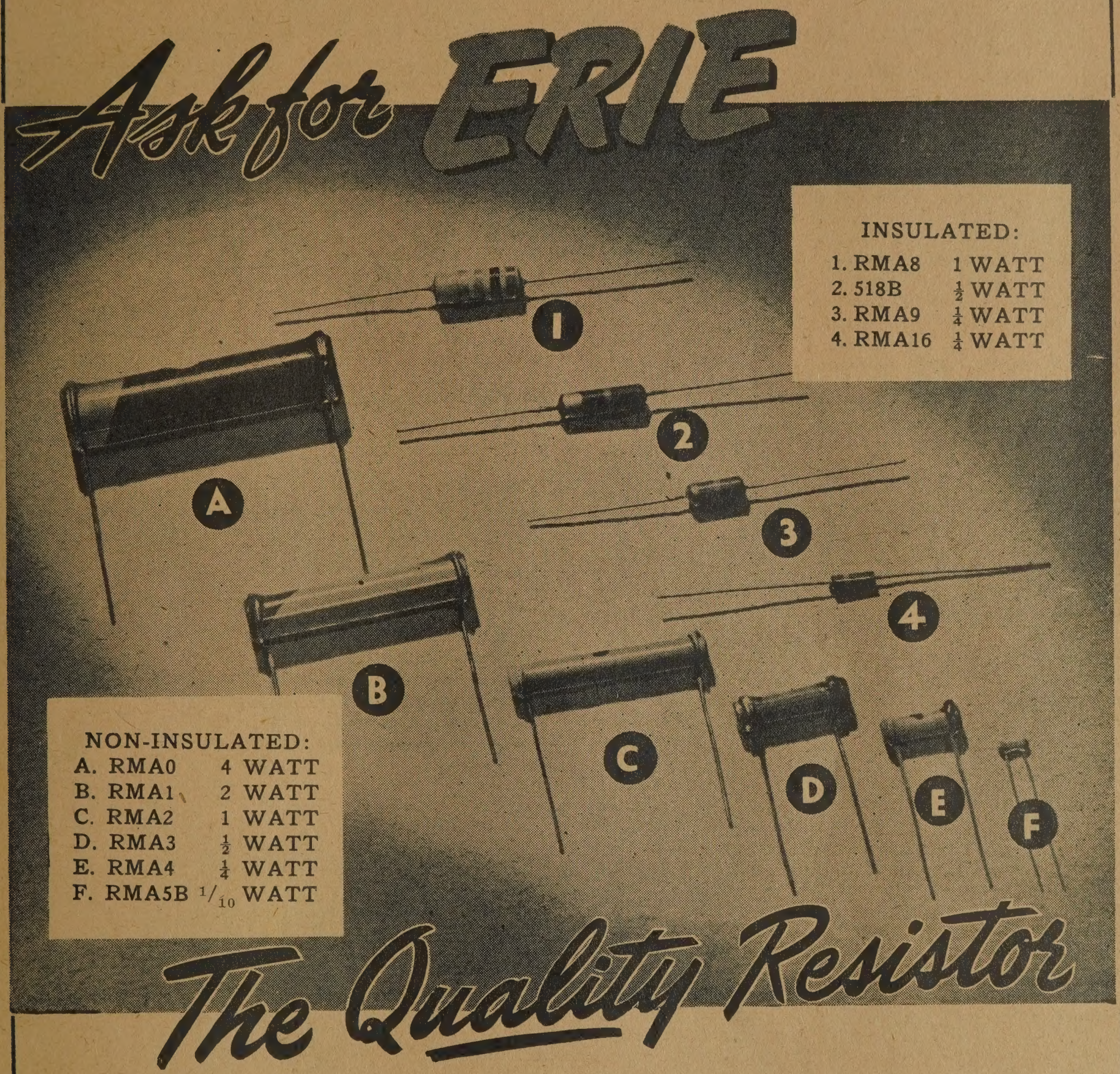
To the originators of the scheme great credit is due and it is important that this should be realised, for the "what do we want with an atomic pile" attitude is an exceedingly short-sighted one, which cannot lead us forward.

AN INCREASE OF PRICE

It is with considerable regret that we have to announce an increase in the price of *Radio and Electronics*.

The necessity for this has been brought about by several factors. Most serious of all has been the increase, over the last twelve months, in the cost of paper and printing. In addition to this, the size of the journal and the quantity of technical material contained in each issue have also shown large increases. In fact, commencing with the October issue, *Radio and Electronics* will be larger still. All these factors have contributed to the rise in price, which though unfortunate, is unavoidable.

We feel sure, however, that the exceedingly generous support which has been accorded *Radio and Electronics* by its readers will continue notwithstanding, and that in return we can keep our promise to readers of an ever-improving and more comprehensive publication.



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ELECTRONIC MUSIC

By C. R. LESLIE, A.M.Inst.M.I.T. (Member Electronic Music Group).

PART II
DEVELOPMENT CONSIDERATIONS

The development of any musical instrument entails the consideration of three essentials: (1) an initiating force to cause, (2) vibration of an elastic body, and (3) a resonator to amplify the vibrations to audible intensity. The initiating force may consist of the striking of a key, release of an air pressure valve, the bowing or plucking of strings, vibration of a reed, and so on. With an electronic instrument the initiating force is standardised in the form of an electric power supply, to which is added mechanical methods of controls for circuit keying, volume level, and tonal response. An electrical waveform generator produces a representation of the vibrations of "an elastic body," and thermionic amplification in association with an electro-acoustical device takes the place of the resonator.

For the simulation of a conventional instrument, fidelity and quality of reproduction will mainly depend on the electrical vibrations generated, and, to a lesser extent, on the electro-acoustical reproducing device. Collectively, fidelity and quality are solely dependent on the correct percentage admixture of harmonics at their particular intensity levels. That is, the fundamental and the harmonic components can be separately generated as pure sine-waves and then sounded simultaneously to produce a particular tone colour. This idea is evident in the electromagnetic harmonic generator comprising a rotating iron disc with a large number of concentric ridges whose faces were moulded with varying sine-wave frequencies, as mentioned in our previous article. But, in addition, it must be remembered that the translating device, e.g., loudspeaker, and the design and constructional material of the containing cabinet will produce resonances which will combine with the electrically-produced vibrations and must be taken into account.

In practice, advantage should be taken of this latter fact to reduce the number of electrically-generated harmonics required to differentiate between characteristic timbres, as, for example, between wooden and metallic instruments.

These remarks will cover the requirements of the sustained note tone colour, but to complete the differentiation between individual instruments it is necessary to introduce transient frequencies to represent the "attack" or playing techinque, and hence they are of considerable importance. These transients are "accidental" in nature, that is, they need not bear any harmonic relationship with the particular note played, so that it is possible to arrive at some compromise that will cover a whole range of notes with acceptable accuracy and thereby reduce the complexity of the circuit.

It will be found that the oscilloscope will afford considerable assistance in practical work for comparison purposes. If the oscillogram of any particular instrument is known, the results of the introduction of any modifications in the waveform generating circuit become immediately visible.

Exact imitation is not required as long as we obtain a general similitude. Research in this field has proved that oscillograms of sustained notes from various instruments of the same type differ quite considerably. The predominant harmonics of any particular type of instrument form the main foundation for circuit design, and then trial and error modifications may be introduced and judged by their reproduced acoustic results.

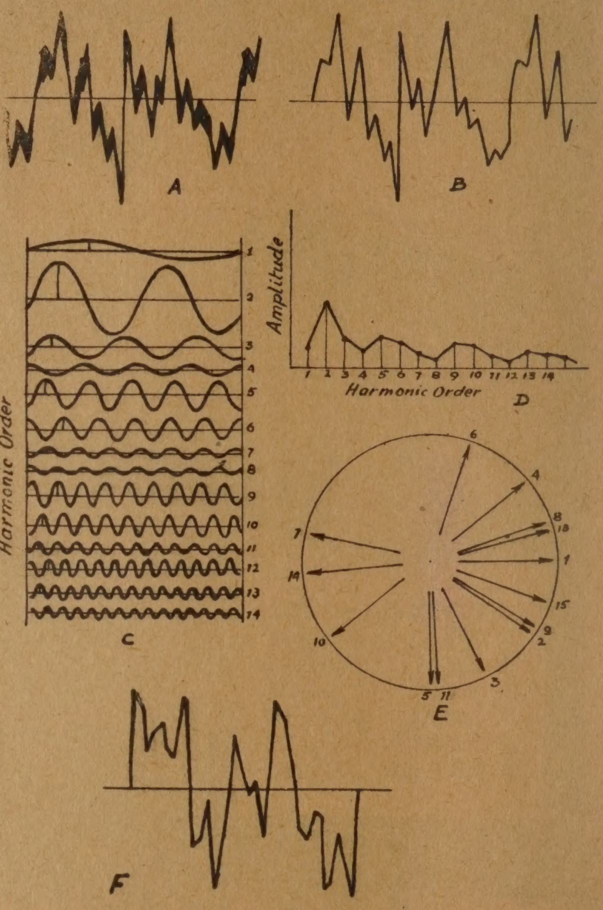

Fig. 5.

Quantitative analysis of complex waveforms is not a simple matter—it can be done mathematically through a very tedious operation, while for many years research work has been carried out to achieve instantaneous electronic analysis. Except for low frequencies, results have not been entirely satisfactory. Steady periodically repetitive complex waveforms can be analysed by singling out individual harmonic frequencies and then measuring their amplitude relative to the fundamental, but carefully constructed equipment is required even for this.

Fig. 5 (A) shows an oscillogram of a steadily-bowed violin string, and at (B) it has been simplified into a thin line form for greater clarity. (C) shows the complete analysis up to the 14th harmonic, while (D) is a spectra diagram for the comparison

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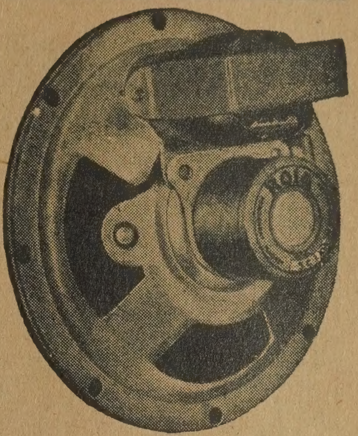

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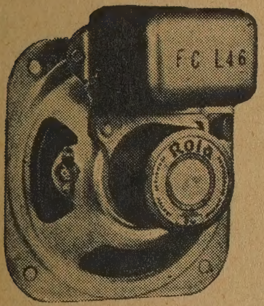

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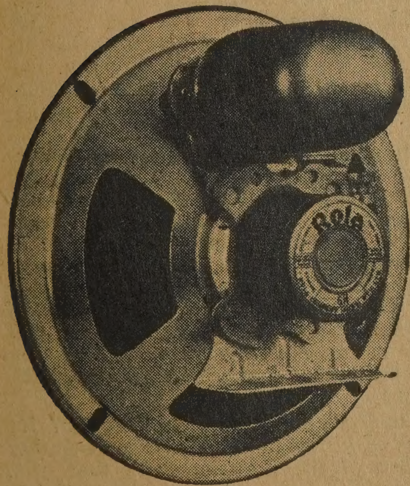

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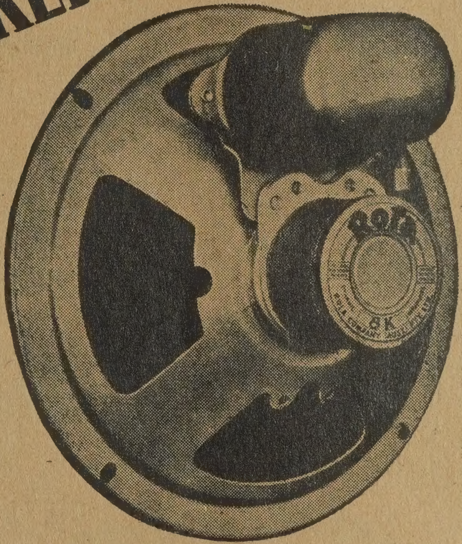

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of individual harmonic amplitude. (E) is a phase diagram which can be ignored in practice, as the ear is not very responsive to phase variations. The spectrum diagram is the most important, as it shows the predominant, and therefore typical, harmonics. A predominant peak appears at the second harmonic with lesser but appreciable ones at the 5th and 9th/10th harmonics. The second is only four and a half times the amplitude of the fundamental (1st harmonic), and therefore it has been stressed some

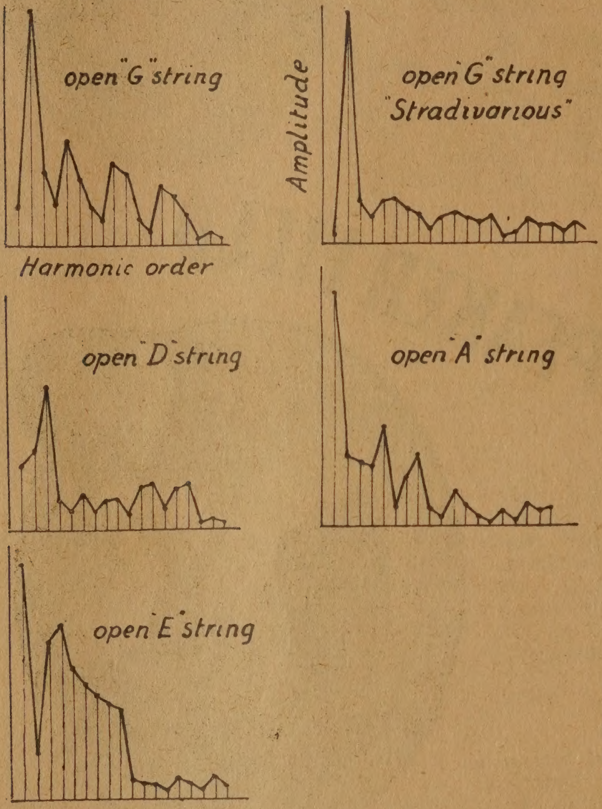


Fig. 6.

900 per cent.—since the unstressed amplitude would be half that of the fundamental. Similarly, the 5th is two and a third times the first, and hence stressed some 700 per cent., and the 9th is stressed some 1500 per cent. and the 10th some 1300 per cent. With this data we can now draw a fresh curve embodying these stressed harmonics and the fundamental only as shown at (F). Comparison of the curves at (F) and (B) shows them to be very much of the same order, and (F) would certainly serve as a circuit design foundation. The actual acoustic result of the curve would probably be a falling-off in brilliance, which would have to be compensated for by modifications which might be found to be of quite a simple nature, such as special selection of speaker, or in its method of mounting.

The above receives corroboration in the recent intensive research work carried out by F. A. Saunders into the performance of many makes of violins, both new and old, using a method of bowing that eliminated performer idiosyncrasies. It was found that the response curves individually varied, though all showed the same peak tendency at about C or C sharp on the G string, which represented the resonance of the contained air. The research also evidenced the fact that harmonic content and amplitude varied (a) with the frequency of the fundamental, being richer and more numerous on the lower notes where the fundamental was suppressed, and fewer and less stressed on the high notes, where the fundamental predominated; and (b) that the harmonic

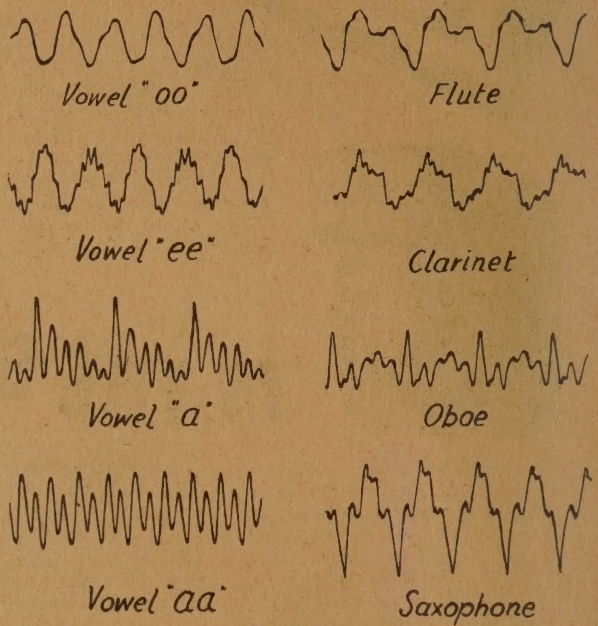


Fig. 7.

content and amplitude varied considerably with the manner of "attack" and intensity. The quality (full harmonic content) varied from instrument to instrument, not only over the whole range of pitch, but at varying points in the pitch range as well. This was due to differences in material and construction and even to the glue and varnish used.

It should be possible to produce more uniformity in electronic instruments, but, since the human ear response varies with the individual, it would be necessary to first compile data obtained from a large number of listeners before mass production could be entered upon unless some system of overriding quality control were introduced. It may be assumed that similar remarks concerning the individual quality of other types of instruments will also hold good and for much the same reasons. The above findings are all in favour of the use of a simplified waveform as a circuit foundation.

Fig. 6 shows the harmonic spectrum diagrams for the four strings of a typical good violin, together with a comparison of the G string with that of a Stradivarius. It will be noticed that the "Strad" has a very suppressed fundamental, a predominant 2nd harmonic, and very much lesser peaks at the 5th, 6th, 10th/11th, and 14th harmonics. The contour generally after the 2nd is very much smoother than that of the other violin, and would account for the greater mellowness of this famous make.

In Fig. 7 we have oscillograms of certain speech vowels and some orchestral instruments by way of comparison and as a matter of interest, as it shows the possibility of making an electronic talking machine, keyed perhaps like a typewriter with phonetic shorthand symbols!

We have mentioned that harmonic content and amplitude varied with intensity of "attack"; this fact is illustrated in Fig. 8, where spectrum diagrams are given of the same note played at three loudness levels.

CHOICE OF SYSTEMS

If we are not going to bother about simplifying the playing technique, the most direct approach would appear to be to use a conventional instrument without its mechanical resonator, and incorporate electromagnetic pick-ups, finishing off with ordinary thermionic amplification and loudspeaker reproduction along normal lines, as, for example in the commercial "electric guitar," which plugs into existing radio sets for the final stages. This is a similar principle to that used in the earlier electric pianos mentioned in our previous article. The question arises whether much is gained by such methods, apart from the increase in volume depending on the amplification of the radio set. It would seem that a fuller satisfaction might be realised if the playing technique were simplified and the whole instrument constructed as a complete unit.

For the production of single voice instruments, probably thermionic solutions will be found to be suitable, as the playing technique can be vastly simplified according to the system used. Oscillation frequencies can be controlled by the variation of resistance, capacitance, or inductance, or by a combination of these means. Probably the first two are the simplest mechanically in practice. Resistance can be conveniently varied by use of a resistance wire wound on a specially-shaped former to suit the response characteristics, or by pressure on a mass of granulated carbon, and thirdly by the use of a photocell. In 1945 Mr. W. Saraga read a paper to the Music Group on an instrument he had constructed using the third method in order to produce a very simple playing manual. This consisted of a box housing the cell, and in the lid of the box was a V-shaped transparent slit to admit light from directly above. The hand is passed across the slit to vary the amount of light reaching the cell. Further details of this instrument can be obtained from the July issue (1945) of *Electronic Engineering*.

Capacitance can be varied in a great many simple ways, but the system generally involves the use of the heterodyne principle, as, for example, in Goldberg and Sohne's instrument mentioned in Part I.

If we decide to use thermionic oscillators, we have the choice of two main lines to follow: either to commence with a pure sinewave and subsequently add the desired harmonics by separate generation, or to kick off with a waveform rich in harmonics and amplify those we require and suppress the others by filtering. The choice will be mainly influenced by the type of instrument we may wish to develop—an electronic flute, for instance, has a waveform very poor in harmonics, and a slightly impure sinewave would constitute a good start. A violin, on the other hand, would probably evolve satisfactorily from an initial saw-tooth type of waveform as produced by a relaxation oscillator.

The recent advances made during the war in the production of super-midget valves may play a big part in the future evolution of the more complex multi-note instruments, as well as the humbler single-voice cousins. Undoubtedly there is a lot to be said for the motor-driven unit for harmonic generation for compactness of size and comparative simplicity of construction, though it should be emphasised that

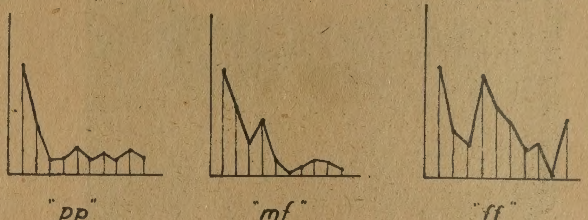
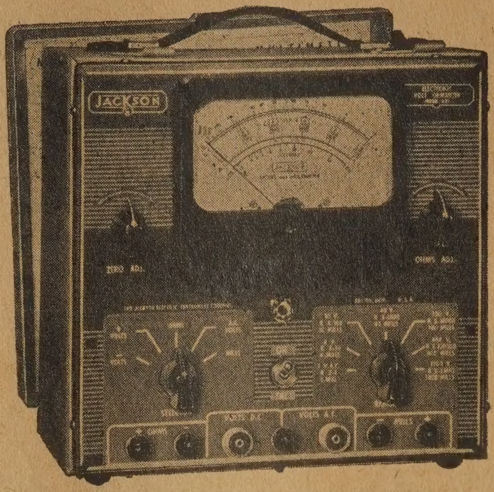


Fig. 8.

the construction must be definitely precision work. Although the completed article may appear to be very complex, close inspection would probably reveal much repetitive work of comparatively simple units —a form of construction used in the Hammond organ. The important point in such instruments is to ensure constancy of motor speed, otherwise frequency fluctuation will result. Where all the 12

(Continued on page 48.)

RADIO TESTING EQUIPMENT



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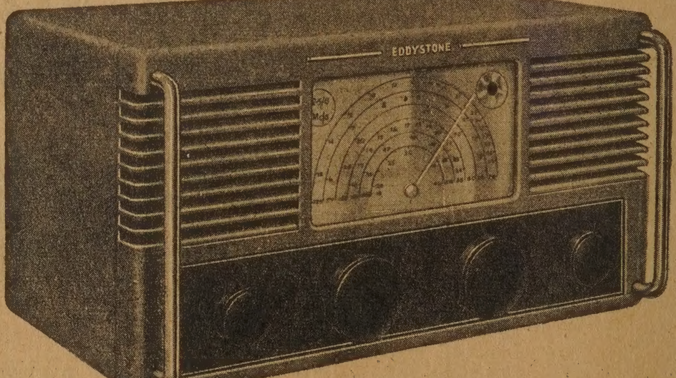

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THE SYNCHRODYNE

As was mentioned in our last month's Editorial, Dr. D. G. Tucker, of the British Post Office Research Station, has invented a type of radio receiver which has the somewhat revolutionary property of possessing extreme selectivity and any desired bandwidth at one and the same time. Here is an article in which the functioning of the synchrodyne receiver is described, and some practical hints are given on its operation and use.

PRINCIPLE OF OPERATION

The general scheme of the synchrodyne is illustrated by the block diagram, Fig. 1. The two dotted squares between the aerial and the one marked "Demodulator" may or may not be necessary, and are included for sake of completeness. The important thing is that a demodulator is fed with signals from the aerial, after optional amplification at radio frequency. Also fed to the demodulator (or mixer, if that term makes one feel more at home) is the output of an oscillator. So far the system would appear to have distinct affinities with the superheterodyne—and so it has, but with a difference.

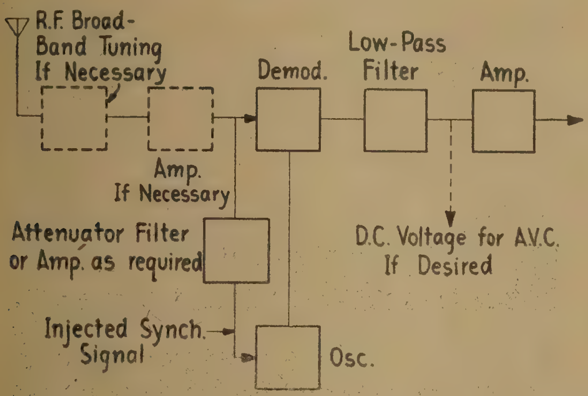


Fig. 1. Block diagram of the synchrodyne.

In the superhet., the oscillator and signal differ by a fixed and known frequency—the intermediate frequency. In the synchrodyne, however, **the oscillator has exactly the same frequency as the signal carrier.**

Again, in a superhet., the mixture of signal and oscillator frequencies is rectified so that a new frequency appears, equal to the difference between oscillator and signal frequencies. This is the I.F. The original signal, however, was modulated, and one way of regarding the signal is as a carrier, together with sideband frequencies, which are spaced from the carrier by amounts equal to the audio frequencies which they represent. Thus, if the transmitter is being modulated by a single tone of 5000 c/sec. (or 5 kc/sec.), the signal will consist of a certain amount of output at the carrier frequency, together with definite amounts of output at frequencies of (carrier + 5 kc/sec.) and (carrier — 5 kc/sec.).

When such a signal is passed to the mixer of a superhet., it is transformed into a new signal, whose carrier frequency is at the I.F., and whose sidebands are at (I.F. + 5 kc/sec.) and (I.F. — 5 kc/sec.).

The sidebands can be considered to produce their own difference frequencies with the local oscillator, and in this way the new signal at I.F. has its own sideband frequencies, still representing the original modulation frequency.

Now, let us consider the set-up in the synchrodyne. Here the oscillator is at zero-beat with the carrier frequency, because we have assumed the two to be on **exactly** the same frequency. Now the upper sideband frequency and the oscillator produce a difference frequency of 5 kc/sec., and so do the oscillator and the lower sideband frequency, so that the output of the demodulator, or mixer, contains only the modulation frequency, or 5 kc/sec.

Perhaps the shortest way of describing the synchrodyne action is as that of a "superhet." whose I.F. is zero cycles per second, with the result that the sidebands become audio frequencies instead of new sidebands, close to the I.F.

WHENCE THE NAME?

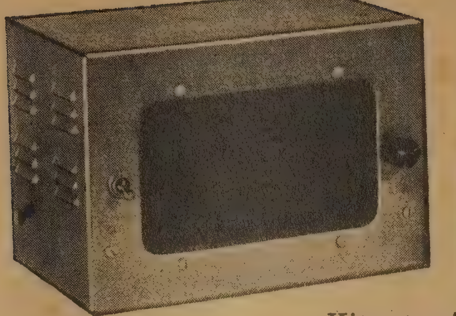
So far we have said nothing at all about how the local oscillator is made to work exactly at the signal carrier frequency, and achieving this in a satisfactory manner is one of the obvious hurdles to be surmounted if the new type of receiver is to be a practical proposition.

It is well known that if a small amount of current, very close to its own natural frequency, is fed to an oscillator, the latter will cease to operate at its own frequency, but will lock or synchronise to the frequency that is injected. Thus the synchrodyne derives its name, for, as the block diagram of Fig. 1 shows, a certain amount of signal is fed to the oscillator after either amplification or attenuation, whichever may be required. Its purpose is to synchronise the oscillator exactly with the carrier. Since the receiver depends for its success on the synchronising action, it has been given the name "synchrodyne."

SELECTIVITY

So far, nothing has been said about the selectivity to be expected with the synchrodyne, or the purpose of the block labelled "low-pass filter" on Fig. 1. In order to see what will happen if other signals are close to the desired one, Fig. 2 has been drawn. At the top of this figure we have three carriers, one on 1000, one on 990, and a third on 980 kc/sec. For purposes of illustration, we have assumed that the 1000 kc/sec. carrier is being modulated by a note of 5000 c/sec., so that this carrier's sidebands are at 1005 and 995 kc/sec. respectively. Similarly, we suppose that the 980 kc/sec. carrier is unmodulated, and that the 990 kc/sec. one is modulated at 2500 c/sec., so that its sidebands lie at 987.5 kc/sec. and 992.5 kc/sec. respectively. Ignoring the higher sideband of the 1000 kc/sec. carrier, the other frequencies present have been labelled from right to left, A, B, C, D, E, and F.

Underneath, in Fig. 2, we have the state of affairs after demodulation, assuming that the 1000 kc/sec. carrier represents the desired signal and, therefore, that the local oscillator has been tuned to lock in on the 1000 kc/sec. carrier frequency. In the lower pic-



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THE CONTROL HEAD contains the volume control, tuning-knob, and easily-read etched glass slide-rule dial, sloping for greater visibility from the driving position. It is of small size, suitable for convenient mounting in any car, either under the dash panel, in a glove pocket, or in any position easily reached by the driver. Mounting is made easier by the fact that the Head is connected to the Speaker Unit by a completely flexible cable, which may be bent or twisted in any way. This allows greater freedom in choice of mounting position of both the Head and the Speaker.

THE SPEAKER UNIT is especially compact, its small size, $8\frac{1}{4}$ in. x $5\frac{3}{4}$ in. x $5\frac{3}{4}$ in., enabling it to fit easily on to the fire wall of any car, where it is held by a single mounting bolt. On its front panel is the continuously variable tone-control knob and power switch. The unit houses the power supply, I.F. and audio amplifiers, and P.M. speaker.

THE CIRCUIT consists of a 6SK7 tuned R.F. amplifying stage coupled by means of a special adjustable aerial matching system to any low-capacity car antenna, preferably of the vertical type. A 6SA7 mixer value gives low noise level conversion of the signal to intermediate frequency, which is fed down to the I.F. amplifier in the speaker unit.

Iron-cored I.F. transformers are used in conjunction with another 6SK7 valve to obtain maximum possible I.F. amplification. The 6Q7 and 6V6 valves form an efficient audio amplifier, and the permanent magnet speaker, by using no field excitation current, ensures lowest possible battery drain. This is about 5 amps. at 6 volts.

High-tension power is provided by a 6X5 rectifier valve, heavy duty 250-volt transformer, and a quiet, low-hash, non-synchronous vibrator. All traces of hash are eliminated by suitable chokes, by-pass condensers, and efficient cadmium-plated housings, and a resistance-capacity filter gives hum-free smoothing with no choke windings to corrode and burn out.

Spark interference is dealt with by the latest methods of suppression, both in the aerial circuit and the power input section. Extra large spark plate, double shielding, bonding of housings, etc., and low-pass aerial filter are all features which assist in preventing reception being marred by ignition and generator noises. Except in difficult cases, no spark plug suppressors are needed on the car itself, and these exceptions can usually be completely filtered by a single distributor suppressor or generator condenser.

The two units are attractively finished in fine crackle, and the shaped cord speaker grille, and pressed-out celluloid dial bezel give the machine a neat overall appearance.

The KIT-SET is complete with all components for assembling the machine, soldering iron, pliers, and screwdriver being the only additional requirements. All metal work parts are punched to fit neatly into place, and the chassis shields, housings, etc., are cadmium-plated for good contact, easy soldering, and professional appearance.

KIT-SETS NOW AVAILABLE IN THE NEW "ARIEL" 5-VALVE PORTABLE RADIO.

The new "ARIEL" 5-valve portable radio is specially designed for New Zealand conditions, and is the best of its kind anywhere available. The cabinet, finished in hard-wearing, moisture-proof, mock crocodile skin, incorporates the latest in portable design. Narrow for easy carrying, it has a new flush-fitting handle and hinged panel-protecting cover, features which help to make the set really portable—easy to carry and stow with other luggage.

Powered by standard-size portable "B" and "A" batteries for ready replacements, the chassis itself uses an R.F. stage, high-gain iron-cored I.F. transformer, and sensitive 5 in. P.M. speaker.

Easily-built kit-sets, with complete technical data and wiring diagrams are available for building of both these radios. Write for further details.

Enquiries also invited from Servicemen and Dealers for completed radios or knock-down kit-sets.

WEBB'S Radios LIMITED
11 Wellesley St. E.
AUCKLAND

ture are shown the beat frequencies which arise, assuming that there is no selectivity between the aerial and the demodulator. Zero frequency is at the left-hand side of the scale.

First of all, the oscillator beats with the 995 and 1005 kc/sec. sidebands of the desired signal giving an output at 5 kc/sec., this being represented by the thick line at B. This frequency is the desired modulation. The oscillator also beats with the 992.5 kc/sec. sideband of the 990 kc/sec. carrier, to give an output

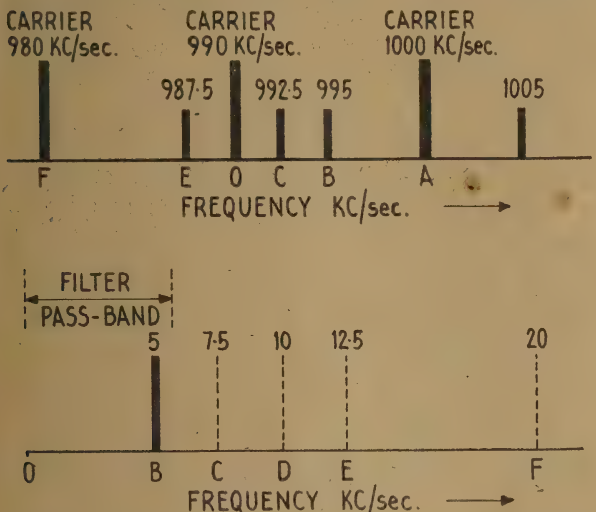


Fig. 2. Showing heterodyne frequencies in the output.

at 7.5 kc/sec. Similarly, beats at 10, 12.5, and 20 kc/sec. are produced with the 990 carrier, the 987.5 sideband, and the 980 carrier respectively. These output frequencies are shown in the lower diagram at D, E, and F.

Now, unless something was done about it, all four frequencies C, D, E, and F would be produced at the set's output (if the audio amplifier were a good one) and would clearly constitute severe interference. However, as the block diagram, Fig. 1, indicates, a low-pass filter is placed between the demodulator and the audio amplifier. This filter for the case we have taken in Fig. 2, would have a cut-off frequency at, say, 5500 c/sec. In other words, it would pass all audio frequencies from zero to 5500 c/sec. substantially without attenuation, and would very strongly attenuate all higher frequencies. Thus the interfering signals would not be heard at all.

WHY SELECTIVITY CAN BE OUTSTANDING

At the beginning of this article it was stated that the selectivity of the synchrodyne is extreme, and that the bandwidth could be anything that was desired. It is now possible to see how this absolutely unheard-of state of affairs comes to exist. The point is that the ability to separate unwanted signals from wanted ones (or, in short, the selectivity) is entirely dependent on the characteristics of the low-pass filter, and does not depend in the least degree on separating signals at some radio or intermediate frequency by means of tuned circuits.

Of course, in the example given, the bandwidth is limited to 5000 c/sec. if all interference is to be eliminated, but this is only because we have assumed stations to be within 10 kc/sec. of each other, as is the case in England and Australia. If stations are separated by intervals of 20 kc/sec., and handle audio frequencies up to 10,000 c/sec., the filter could be designed to cut off at about 9500 c/sec., so that complete discrimination would be obtained against adjacent signals, and yet all audio frequencies up to higher than 9000 c/sec. would be available for the audio amplifier to reproduce.

Of course, the selectivity of the synchrodyne depends not simply upon the fact that a low-pass audio filter is used to achieve it, but on the ease with which such a filter may be constructed. In an ordinary receiver, the attempt to realise a flat top to the selectivity curve, so as not to attenuate the higher modulation frequencies, is in direct opposition to the simultaneous requirement of very steep sides to the selectivity curve. In an audio filter, the cut-off may be made very sudden indeed with only simple filter circuits, so that one escapes almost completely from the difficulties inherent in constructing band-pass filters at radio frequencies.

VERY NARROW BAND USE

Owing to the method whereby the synchrodyne achieves its selectivity, it is just as easy to give it selectivity and **narrrow** bandwidth as to realise selectivity with a wide-pass band. For example, in order to get a result comparable with that obtained from a cystal filter, it is only necessary to give the audio low-pass filter a cut-off at 500 or 250 c/sec.

It is the possibility of doing this that gives the synchrodyne its potential value in a communications receiver.

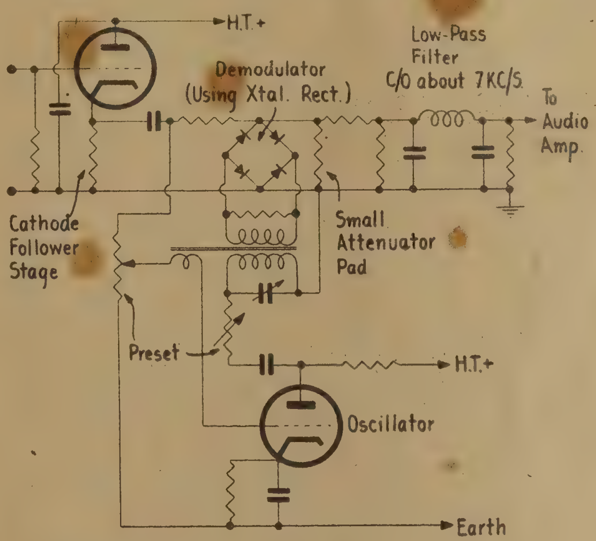


Fig. 3. Circuit due to Dr. D. G. Tucker.

ACTUAL CIRCUITS

Having said something about the principle of the synchrodyne, the time is opportune to delve a little further and discuss some of the practical points involved. Fig. 3 is a reproduction of the circuit given in his article by Dr. Tucker. No values are stated, but the circuit is sufficiently detailed to enable an estimate to be made of some of the practical issues involved.

First of all, Dr. Tucker shows a cathode-follower stage, the output of which is fed to the mixer, which in his case is a bridge rectifier system using copper oxide or other small cartridge-type rectifiers such as the 1N34. There is a series resistor between the cathode follower output terminal and the bridge rectifier, and a potentiometer between cathode-follower output and earth. The oscillator is a normal plate-tuned tickler feedback type in which the grid winding instead of being returned to earth is returned to the moving arm of the aforementioned potentiometer. By this means a controllable amount of signal is fed to the oscillator grid, so that when the frequency of oscillation approaches sufficiently close to that of a signal, locking occurs. At the output of the demodulator is the low-pass filter consisting of a single pi-section, preceded by a pi-section attenuator pad. At the output of the filter is a load resistor which acts both as a load for the rectifier and as a correct termination for the filter.

Now, a bridge rectifier of the type shown is a low-impedance device, so that the third winding of the oscillator coil assembly has comparatively few turns, and matches the oscillator to the rectifier circuit. One difficulty with the circuit of Fig. 3 is that, unless the load resistance for the rectifier is quite high, the audio output will be very small. The audio amplifier can make up for this, however, so that mere low output is not of much consequence. The real difficulty with Dr. Tucker's circuit is that, if the load resistor is kept high in value to ensure as much output as possible, the filter requires quite a high value of inductance. This, in turn, would have to be iron-cored, in which case it would be difficult design with low enough losses for a single filter section to give adequate rejection in the stop-band and to have a sharp enough cut-off. The filter must be designed with regard to the circuit impedances in to and out of which it is to work. The purpose of the attenuator pad is to act as an impedance matching device between the rectifier and the filter and at the same time to isolate the shunt capacity of the filter from the rectifier circuit.

THE LOCKED OSCILLATOR

The type of locked oscillator shown in Dr. Tucker's system would be quite difficult for the ordinary worker to design, and would necessitate much experimentation with tickler coupling and stabilising resistor before the best values are hit upon. Since Dr. Tucker has not seen fit to give any indication of circuit constants in his article, it was necessary either to indulge in a good deal of "cut and try" or else to devise a scheme which would make oscillator locking easier.

The circuit of Fig. 4 was therefore devised with a view to making a basis for simple experimentation by others.

A PRACTICAL CIRCUIT

Fig. 4 shows one scheme that can be made to work quite easily. A pair of 6H6's was substituted for the crystal rectifiers, and the circuit is exactly that of the original. On the diagram, the cathode-follower input stage has been omitted. The aerial can be taken either directly to the input terminal shown, or a pre-selector (such as the one described in the August, 1947, issue of "Radio and Electronics") can be used to feed the circuit.

The oscillator is now a transitron, which was chosen because of the ease with which it may be locked by a small signal on the grid. The oscillator coil and tuning condenser are standard broadcast components. The coil used is not an ordinary "oscillator" coil, since this would not cover the whole broadcast band, but is made from an ordinary R.F. coil as follows. The secondary is left untouched, and is used for the tuned winding, thus covering the broadcast band. The winding normally used as the primary is used to couple the oscillator output to the diode circuit, but must be modified for best results. First, its connections are unsoldered from the lugs on the former. Then the whole coil is placed, primary downwards, on a soldering-iron which has just been turned on and is starting to warm up. When the wax round the primary has started to flow, this winding is carefully pushed up the former until it is within ⅛ in. of the secondary. It is then allowed to cool off, when it will be held firmly in position by the wax. Now, turns are unwound from the primary until its remaining winding is about half the depth of the secondary. The wire is now spotted in place with some wax and the leads are re-soldered.

Although the oscillator circuit given worked with either of the three types of tube mentioned in the diagram, the 6SK7 was found to be the most satisfactory one. There is no reason why other tubes such as the 6D6 or 6U7-G should not work equally well in the circuit.

The next modification to the original circuit was to install a cathode-follower between the demodulator and the audio filter. The filter section is thus effectively isolated from the diode circuit, and it is possible to give it the low impedance necessary to reduce the value of the inductance to a low value. The filter shown was designed for a terminal impedance of 300 ohms, and uses an ordinary 10 millihenry R.F. choke. It is terminated at the output end by a 300-ohm resistor, and at the input has 150 ohms connected in series so that the output impedance of the cathode-follower shall not be too low to act as a proper termination. The circuit shown was tested with an audio oscillator, and was found to have quite good characteristics, as the output from 15 to 9000 c/sec. was flat within 1 db., with a very sharp drop thereafter, and good attenuation at all higher frequencies. A normal R.C. coupling circuit takes the output to the audio amplifier. It should be noted that the output is quite low, and an extra stage of audio amplification is necessary over and above the gain provided by the usual amplifier. It is suggested that those wishing to experiment with this circuit would be well advised to put a stage of triode amplification on the experimental chassis and feed the output of this stage to the amplifier proper.

OPERATION

With the circuit of Fig. 4 it is possible to gain a good idea of the possibilities and limitations of the synchrodyne.

First, the signal input to the diodes should be kept quite small, or else the system will act as a T.R.F. and the modulation will be heard before the oscillator is tuned to the carrier frequency. This remark applies mainly to the case where the input to the synchrodyne detector is obtained from a pre-amplifier. Secondly, if too much synchronising signal is supplied to the oscillator it stops oscillating and acts as an amplifier, so that T.R.F. action is again apparent.

It is clear from the method of operation of the synchrodyne that exactly as with an ordinary oscillating detector, a whistle is heard as soon as the oscillator is tuned within audio range of a carrier. This heterodyne whistle is actually a good deal louder than the modulation once the station is properly tuned in, so that it is as well not to have the audio gain control turned up too far when tuning.

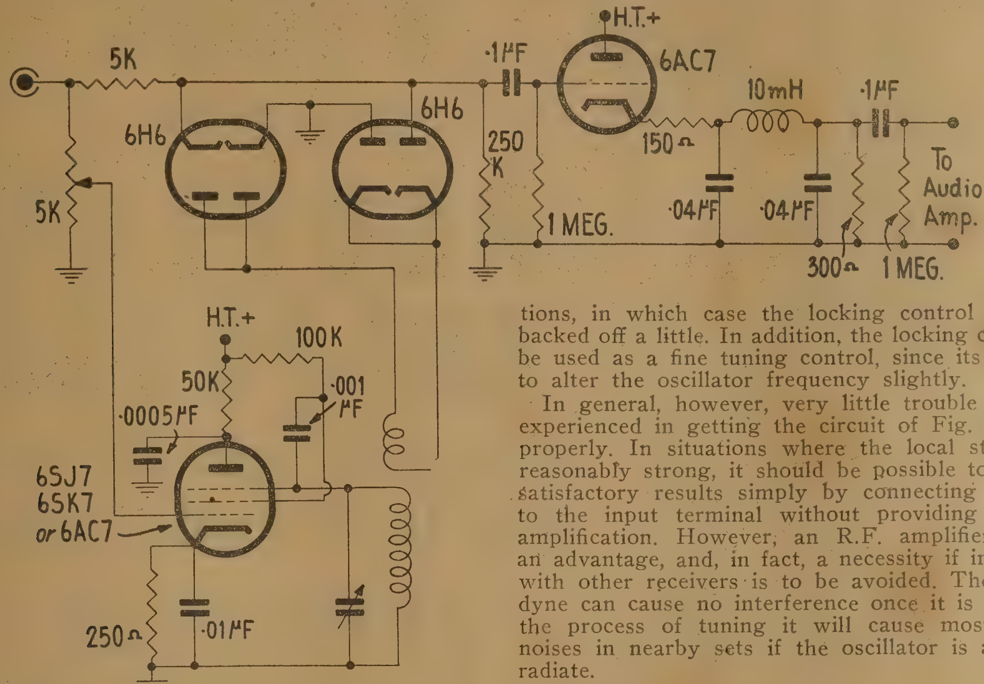


Fig. 4. Experimental circuit constructed in our laboratory

When the receiver is working properly and is tuned across a carrier, the heterodyne whistle decreases in pitch in the usual way and then suddenly stops as the oscillator falls into lock with the carrier frequency. If the oscillator is only just locked and no more, the heterodyne whistle will continue down to a very low frequency before the oscillator locks and the whistle disappears. In other words, the oscillator has to be tuned to within only a few cycles of the carrier frequency before locking occurs. If the oscillator is locking readily, it will be noted that the whistle will disappear after it has reached only a comparatively high frequency, such as 200 or 300 c/sec. This means that the oscillator may be mistuned by 200 c/sec. on either side of the carrier frequency before it falls out of synchronism.

When the oscillator is working in this way, there is no difficulty at all about tuning in a carrier. As long as the oscillator is locked, no heterodyne exists, and the quality of reproduction will be the same irrespective of where the oscillator is tuned within the locking range. Thus the set is either tuned or mistuned, there being no intermediate position between the two conditions, as exists with an ordinary receiver.

ADJUSTMENT OF LOCKING CONTROL

In an experimental hook-up, it is just as well to bring the 5k. locking potentiometer out to the front panel, to facilitate adjustments. The only difficulty likely to be encountered is in setting the locking control in such a way that satisfactory results are obtained on all local stations. Obviously, if the signal from the weakest station is too small for satisfactory locking, the control must be advanced until locking is obtained. In this position, trouble may be experienced through T.R.F. action on the stronger stations, in which case the locking control has to be backed off a little. In addition, the locking control can be used as a fine tuning control, since its use tends to alter the oscillator frequency slightly.

In general, however, very little trouble should be experienced in getting the circuit of Fig. 4 to work properly. In situations where the local stations are reasonably strong, it should be possible to get quite satisfactory results simply by connecting the aerial to the input terminal without providing any R.F. amplification. However, an R.F. amplifier stage is an advantage, and, in fact, a necessity if interference with other receivers is to be avoided. The synchrodyne can cause no interference once it is tuned, but the process of tuning it will cause most grievous noises in nearby sets if the oscillator is allowed to radiate.

POSSIBILITIES OF THE SYNCHRODYNE

The purpose of the present article has been to introduce to readers a new field for experimentation, and no claim is made for the experimental circuit that it is suitable to let loose upon the uninitiated listener! Far from it; but there is no doubt that here is the germ of some very interesting developments.

Some suggestions as to profitable lines for experiment may be useful to readers.

First, the synchrodyne looks like the long-awaited answer to the desire for a high-quality local receiver with unlimited audio frequency response and yet good selectivity. It would be quite possible without further development to design a push-button-operated local receiver which would remove the circuit's disability—that of the heterodyne whistle during tuning.

A suggestion in this connection which would be worth while following up is that an untuned R.F. amplifier should be used to feed the circuit of Fig. 4. This could employ a 6AC7/1852 with a low plate load resistor (say, 1000 ohms) so that a reasonably small gain is achieved together with isolation of the oscillator from the aerial. The best plan would be to supply the full output of this amplifier to the synchronising control potentiometer, and a fraction only to the diode circuit. In this way there should be ample locking signal made available even from comparatively weak stations, and at the same time the input to the rectifier circuit should be kept small enough to prevent T.R.F. action,

With this arrangement, the receiver could easily be arranged for push-button tuning. Push-button switches normally have two levels to each button, one of which is used to switch oscillator tuning and the other the aerial tuning. In this case, one could be used for switching the oscillator tuning and the other for switching in varying amounts of synchronising voltage to suit each station. This would be necessary only if a single setting of the synchronising potentiometer was not suitable for all the stations to be received. If switching of the synchronising voltage is employed, it would certainly not be necessary to provide a separate synchronising voltage for each station, since in most cases two levels of synchronising voltage would suffice. This would simplify the synchronising switching.

USE IN COMMUNICATIONS RECEIVERS

There is room for a good deal of experiment in the use of a synchrodyne as the second detector in communications receivers. Here it would be used to replace the normal second detector circuit, and so would require only a fixed-frequency oscillator, thus giving considerable simplification. It would still have to be worked at a low level, but this could easily be arranged by tapping off a fraction only of the available I.F. output.

The circuit of Fig. 4 could be used as a separate plug-in unit which could be switched in or out in the same way as is sometimes done with crystal filter units in a set which does not have such a filter incorporated.

Its chief use here would be to give super-selective phone reception, which it would do if the low-pass filter were arranged to cut off at, say, 2000 cycles/sec. or even less.

In this application, the A.V.C. would perform a useful and even essential purpose by keeping the input level to the synchrodyne detector reasonably constant for wide variations in signal strength, thus making a single setting of the synchronising control suitable for almost all signals.

The only major difficulty likely to be encountered would be that of an interfering strong signal controlling the sensitivity of the receiver when it is desired to listen to a weak adjacent signal. This would still cause no trouble were it not for the fact that the desired signal would be too weak to lock the oscillator. However, the above suggestion is made purely as a guide to some interesting experiments, for only these will show whether the new circuit can be made to confer the advantages that might be expected of it.

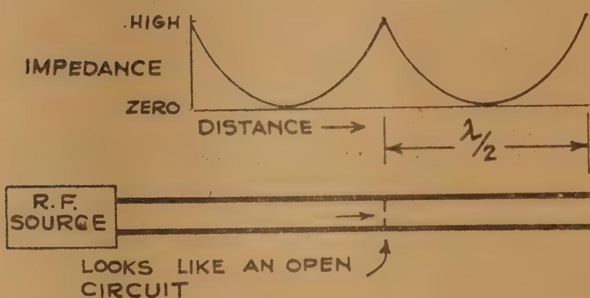
An application where the synchrodyne would appear to confer very great advantages, if the difficulties can be overcome, is a second detector in a superhet. which has a high intermediate frequency, say, 2 to 5 mc/sec. or higher. This is really the same thing as the last suggestion, except for the high I.F. In this case the synchrodyne would confer all

(Continued on page 48.)

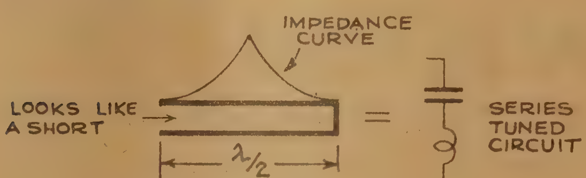
A PRACTICAL ANALYSIS OF ULTRA HIGH FREQUENCY TRANSMISSION LINES, RESONANT SECTIONS, RESONANT CAVITIES AND WAVE GUIDES

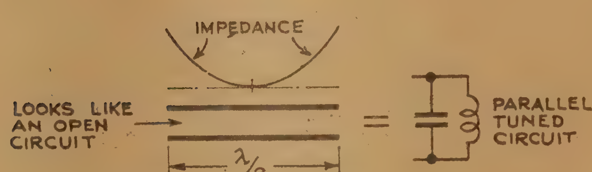
By J. R. MEAGHER and H. J. MAR KLEY, R.C.A. Service Company Inc.

HALF-WAVE OPEN SECTION

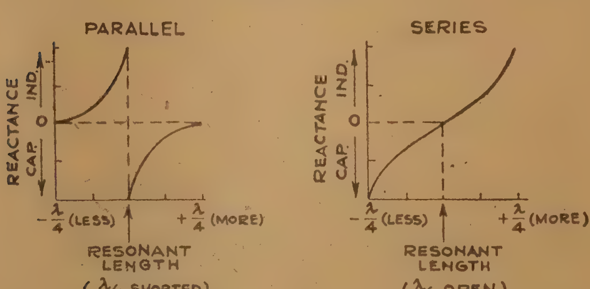


The half-wave open section at the end of the line has high input impedance. This section corresponds to a parallel-tuned circuit.





TUNING CHARACTERISTICS OF RESONANT SECTIONS

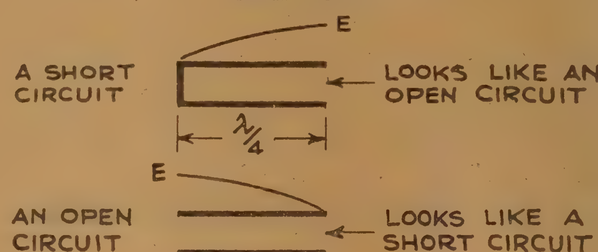


1. Quarter-wave, shorted }
2. Half-wave, open } Equivalent to a parallel-tuned circuit.

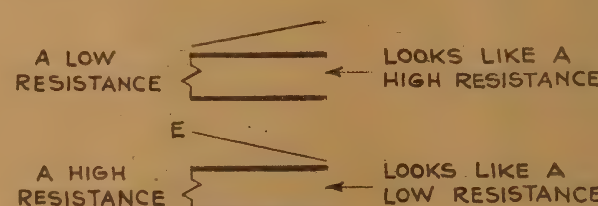
3. Quarter-wave, open }
4. Half-wave, shorted } Equivalent to a series-tuned circuit.

If a section of line is tuned above or below the resonant input frequency (by making the line shorter or longer) the effect is the same as in a conventional tuned circuit. The section will no longer look resistive. Either capacitative or inductive reactance will predominate.

QUARTER-WAVE LINE "INVERTS" THE LOAD



A quarter-wave line "inverts" the load as seen by source.



$$Z_0 = \sqrt{Z_{IN} Z_{OUT}}$$

The input impedance in the above cases can be determined as follows:

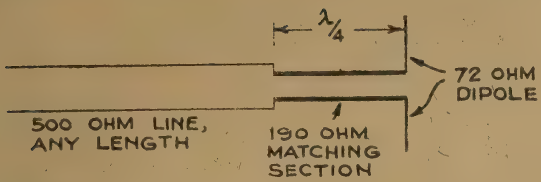
$$\text{Input impedance} = \frac{(\text{Line impedance})^2}{\text{Load impedance}}$$

QUARTER-WAVE MATCHING SECTION

The "inverting" property of a quarter-wave section can be put to practical use when it is necessary to match a line of one impedance to a load of a different impedance. To do this, the section must have an impedance calculated as follows:—

$$Z \text{ matching section} = \sqrt{Z_{LINE} \times Z_{LOAD}}$$

For example: A 500-ohm line can be matched to a 72-ohm dipole through a quarter-wave section of 190 ohms.



The **line** looks into a load of

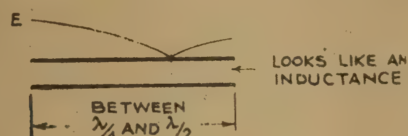
$$\frac{(Z \text{ of matching section})^2}{Z \text{ of load}} \text{ or } 5000 \text{ ohms}$$

The **antenna** looks into a source of

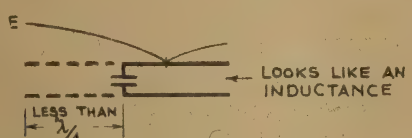
$$\frac{(Z \text{ of matching section})^2}{Z \text{ of line}} \text{ or } 72 \text{ ohms}$$

"INVERSION" OF CAPACITY AND INDUCTANCE

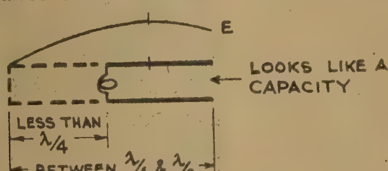
Inversion of capacity and inductance can be explained as follows:—

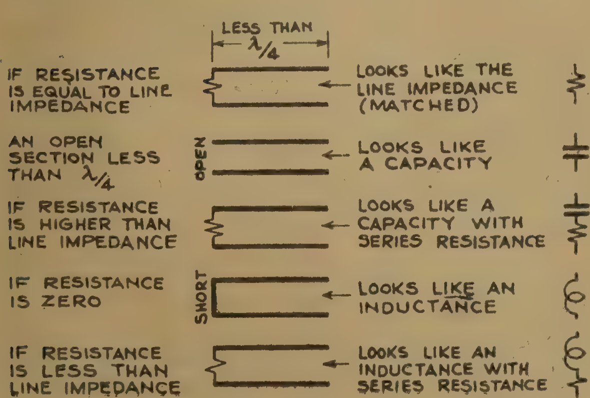


An open section of line between one-quarter and one-half wave long looks like an inductance to the source.



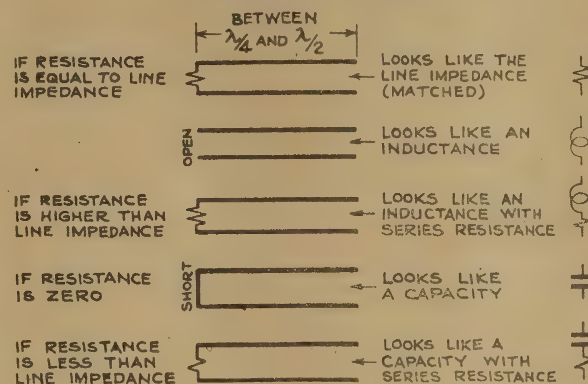
If a part (less than one-quarter wave) is replaced by a capacity (an open section less than one-quarter wave looks like a capacity), the section still looks like an inductance to the source.





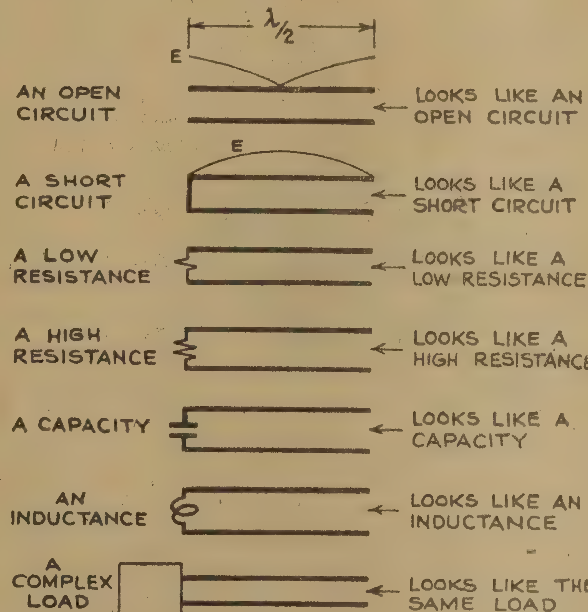
A shorted section between one-quarter and one-half wave looks like a capacity. If part(less than one-quarter wave) of the shorted end is replaced by an inductance, the section will still look like a capacity to the source.

SECTIONS BETWEEN ONE-QUARTER AND ONE-HALF WAVE



HALF-WAVE LINE "REPEATS" THE LOAD

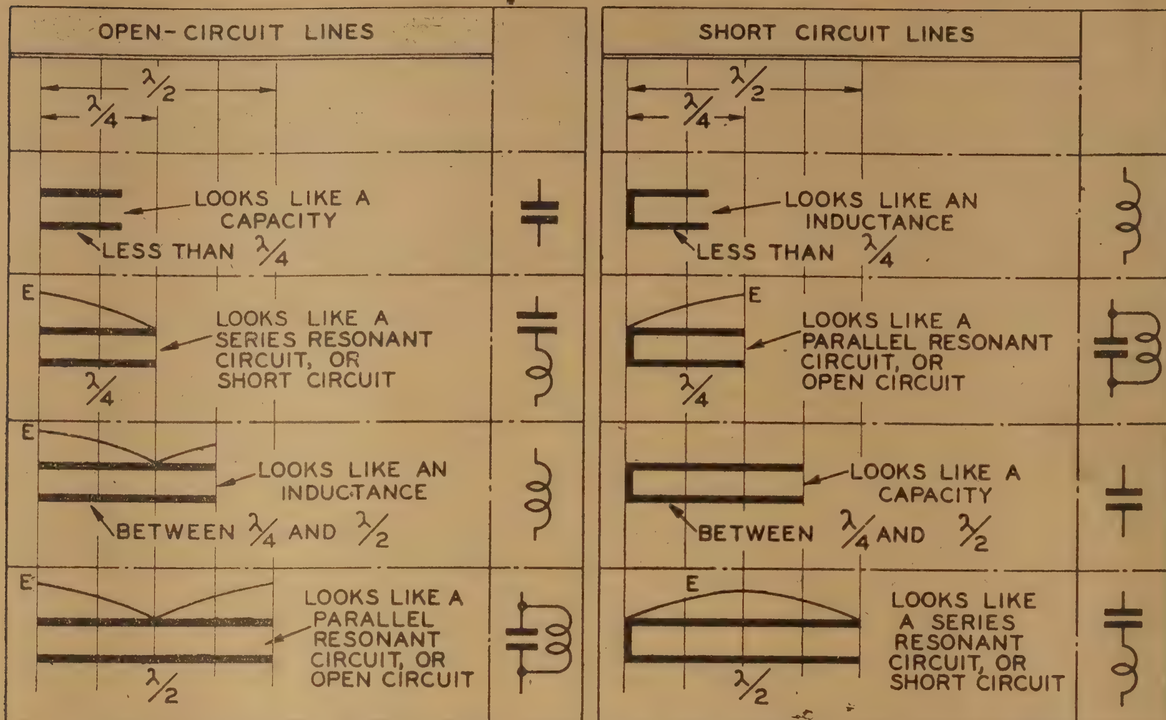
A half-wave line acts as a "double inverter," and hence will "repeat" whatever appears on the far end:



A line that is any multiple of one-half wave has the same characteristics.

The action of a half-wave section, or a line cut to a multiple of a half-wave, is used extensively in practical applications. For example, if a dipole antenna with an impedance of 73 ohms is to be coupled to the output of a transmitter, through an open-wire line (spaced pair) with a characteristic impedance of several hundred ohms, the line can be cut to a multiple of an electrical half-wave.

(To be continued.)



CHARACTERISTICS REPEAT WHEN MULTIPLES OF AN ELECTRICAL HALF WAVE ARE ADDED.

TUBE DATA: *The EL37 25-Watt Power Pentode*

(1) Introduction

The EL37 is a 25-watt pentode particularly suited for use in the output stages of power amplifiers. Although primarily intended for push-pull working, the valve may be used as a single-ended class A amplifier, in which application an audio output of the order of 10 to 12 watts can be obtained with a 10 per cent. limit of distortion.

The valve is single-ended, with an octal base, and the pin connections follow the normal arrangement.

(2) Static Data

The following figures are taken at a plate voltage of 250, screen voltage 250, and grid voltage — 13.5.

Heater voltage	6.3v.
Heater current	1.4 amp.
Plate current	100 ma.
Screen current	13.5 ma.
Mutual conductance	11.0 ma./v.
Plate resistance	13,500 ohms
Grid screen amplification factor	10

(3) Maximum Ratings

Plate supply voltage	550v. max.
Plate voltage	400v. max.
Screen supply voltage	550v. max.
Screen voltage	400v. max.
Heater-cathode voltage	75v. max.
Grid-screen amplification factor bias	0.5 meg. max.
Grid-cathode resistance (fixed bias	0.1 meg. max.
Plate dissipation	25 watts max
Screen dissipation	6 watts max
Cathode current	125 ma. max.

(4) Typical Operating Conditions

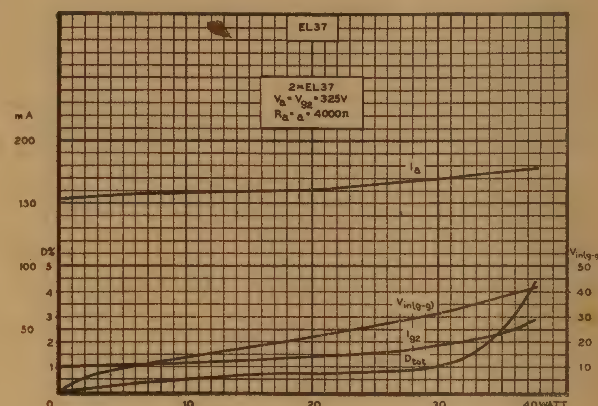
(a) Single-valve Operation

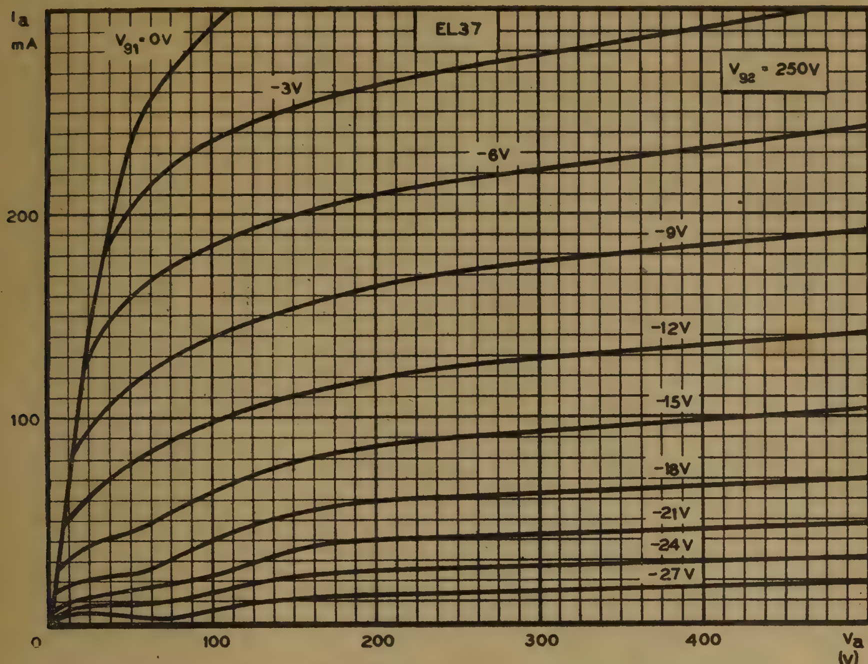
Plate voltage	200	250	300v.
Screen voltage	200	250	300v.
Plate current	78	100	83 ma.
D.C. input power	15.6	25	25w.
Cathode resistance	120	120	215 ohms
Screen current	10.5	13.5	11.5 ma.
Plate load resistance	2500	2500	3500 ohms
R.M.S. input voltage for 50 mw. output	0.5	0.45	0.48v.
Power output at 2.5 per cent. total distortion	0.6	1.0	0.87w.
Power output at 10 per cent. total distortion	6.2	10.5	10.0w.
Power output at start of grid current	6.5	11.5	12.5w.
Total distortion at start of Grid current	12.0	13.5	18%
R.M.S. input voltage at start of grid current	8.0	10.8	13.2v.

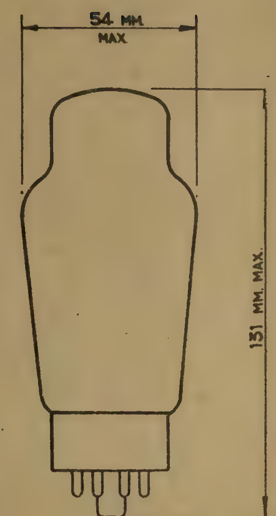
(b) Single-valve Operation with Unbypassed Cathode Resistor

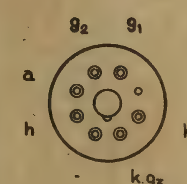
Note.—All values down to and including screen current as the same as for (a) above. This type of operation gives lower distortion at low-signal levels than obtained in (a) above.

Plate load resistance	2200	2200	3000 ohms
R.M.S. Input voltage for 50 mw. output	1.25	1.25	1.65w.
Power output at 10 per cent. total distortion	—	—	11.5w.
Power output at start of grid current	6.2	10.5	12.5w.
Total distortion at start of grid current	7.3	9.5	13.5%
R.M.S. input voltage at start of grid current	16.6	22.7	35.7v.









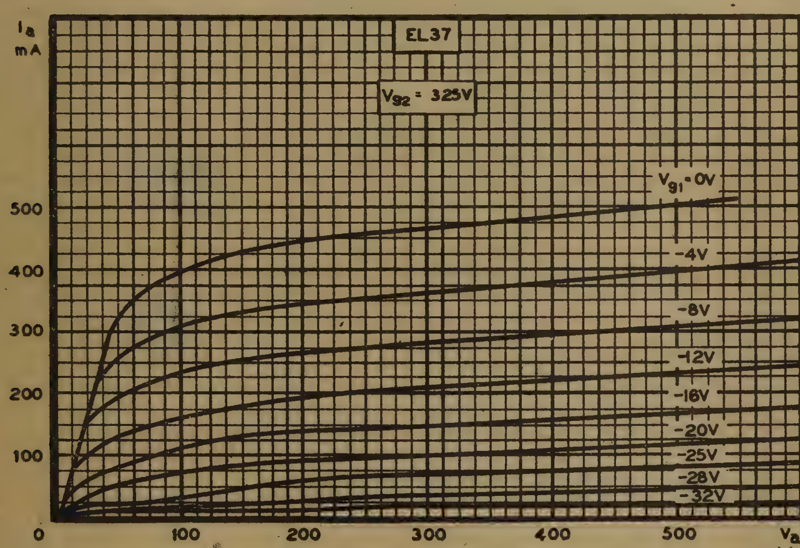


Plate characteristic curves, dimensions and base diagram for the EL37. On the previous page is shown the plate current, peak-to-peak input voltage, screen current and total distortion for push-pull EL37's as functions of power output.

(c) Push-pull Operation, Self Bias

Plate voltage	250	325v.
Screen voltage	250	325v.
Plate current (no signal)	118	154 ma.
Screen current (no signal)	15	19 ma.
Plate current (max. signal)	135	178 ma.
Screen current (max. signal)	35	59 ma.
Power output at less than 1 per cent. total distortion	15	24w.
Power output (maximum)	20	37.5w.
Total distortion at max. power output	2.2	4.4 per cent.
Cathode resistor	130	130 ohms
Plate-to-plate load resistance	4000	4000 ohms

(d) Push-pull Operation, Fixed Bias

Plate voltage	300	350	400v.
Screen voltage	300	350	400v.
Grid voltage	—27	—31	—35v.
Plate current (no signal)	60	80	100 ma.
Screen current (no signal)	8	10	13 ma.
Plate current (max. signal)	—	—	276 ma.
Screen current (max. signal)	—	—	73 ma.
Plate-to-plate load resistance	3750	3250	3250 ohms
Power output at 3 per cent. total distortion	35	50	70 watts

QUESTIONS and ANSWERS

THE CATHODE FOLLOWER AUDIO MIXER

M.P., Auckland, writes:—

"With reference to your interesting article on 'Two New Uses for the Cathode Follower,' I would appreciate your replies to the following questions on the audio mixer circuit:—

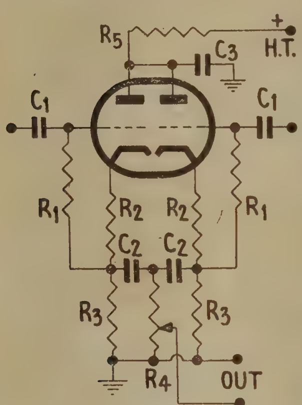
(1) Could three 6SN7's be used to provide a six-channel mixer, the terminating point to be arranged as for C_2-R_4-C_2 on your original diagram?

(2) Could 1 meg. potentiometers be substituted for R_1 and used as gain controls?

(3) Is the value of C_2 correct at 1 mfd.?

(4) Would the frequency response be flat through out the audio range from 30 to 12,000 c/sec.?

(5) If three 6SN7's can be used, could R_5 be reduced to 20k., with a 300v. supply?"



$R_1 = 1$ meg.
$R_2 = 1500$ ohms.
$R_3 = 50$k.
$R_4 = 100$k. pot.
$R_5 = 50$k. (see text).
$C_1 = 0.05$ mfd.
$C_2 = 1$ mfd (see text).

Fig. 1 is the cathode follower mixer circuit referred to.

Taking M.P.'s questions in order:—

(1) There seems no reason why three 6SN7's can not be used to provide a six-channel mixer circuit. The loss in each cathode follower may increase slightly as more of them have their outputs connected in parallel, and how many can be so connected without undue loss is purely a matter for trial. It is not expected that the effect will be at all serious, however.

(2) We do not recommend the substitution of potentiometers for the fixed grid resistance of R_1, as this would tend to make the frequency response dependent upon the settings of these controls. The best scheme for controlling the inputs is to place potentiometers on the other side of the input condensers, C_1. This necessitates a double R C coupling if any one input is being fed from a preceding valve. This arrangement was used in the "Very High-quality 20-Watt Amplifier" described in the August issue of "Radio and Electronics" to couple the output of the pre-amplifier stage V_1 to one side of the mixer.

(3) In the original circuit, reproduced above, R_4 was set at 100k. This value of coupling resistor requires a large value of C_2 in order to preserve the response at very low frequencies, but it could be reduced to 0.5 mfd. without much deterioration in low-frequency performance. If R_4 is raised to 500k., C_2 in each case could be reduced to 0.1 mfd. if desired, these values giving the same low-frequency performance as 100k. and 0.5 mfd.

(4) The frequency response of the cathode follower is flat from below 15 c/sec. to very high frequencies—in the region of 75 kc/sec. This figure holds if R_4 is 100k., and not more than 60 mmfd. is shunted across it by the input capacity of the next stage. If R_4 has been increased to 500k., then the allowable shunt capacity for the above high-frequency response is reduced to 12 mmfd. However, the coupling circuit to the next valve is not really part of the cathode follower mixer circuit, which has a response on its own far exceeding the most stringent possible requirements for audio amplifiers.

(5) If the mixer stage is to handle input voltages as high as, say, 20 volts at each cathode follower grid, then care must be taken that the plate supply voltage is not reduced too much by the decoupling resistor R_5. Under these circumstances, a reduction of R_5 to 25k. or so would probably be advisable. On the other hand, if the mixer is to work at low signal level, say, in the region of a volt, there is some point in keeping the plate supply voltage fairly low through using a high value of R_5.

The purpose of this is to reduce the voltage drop across the cathode resistors and therefore the D.C. voltage that exists in this circuit between heater and cathode. This, in turn, reduces the possibility of hum arising, which would not be troublesome at high signal levels.

BANDSPREADING THE ZC1 RECEIVER

A.B.L., Greymouth, writes:—

"In your February, 1947, issue, Mr. Ralph Slade makes reference to the possibility of bandspreading Z.C.I. receivers by the use of accurately matched mica condensers. I should be very grateful if you would advise me what capacities to use in order to spread the 40 and 80-metre bands over the entire dial."

We are unable to answer this question directly, as we have no figures on the actual coils and tuning condensers used in the receiver tuning unit.

By estimation, the maximum capacity of the gang condenser appears to be in the region of 175 mmfd. In addition, the 3.5-4 mc/sec. band is right at the high-frequency end of the tuning range, so that it should be possible to cover this band simply by placing fixed condensers in series with the gang sections. The exact value is difficult to estimate, but a capacity of 50 mmfd. is suggested as suitable for an initial trial. All that needs to be done is to insert the condensers and find out where the 3.5 mc/sec. end of the band comes on the dial. If the series condensers are too small, the lowest frequency on the dial will be higher than 3.5 mc/sec. If too large, the band will be spread over a portion only of the dial.

It is recommended that silvered mica condensers of ± 1 per cent. tolerance be used to make up the required value. Accurate condensers of this kind are (or were recently) available in sizes of 25, 100, and

(Continued on page 47.)

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VALVE CURVES IN CLASS A AMPLIFIER DESIGN

PART IV: PENTODE POWER AMPLIFIERS

In designing pentode and beam-tetrode amplifiers, use is made of the plate family of curves very much in the same way as has been outlined for triodes. The curves are very different in shape from the triode curves, but the general principles are exactly the same. For example, in either case, if a tube could be made whose characteristics were parallel and equidistant straight lines, a load resistance of any value would give a distortionless amplifier. Similarly, in practical cases with pentodes the load line is chosen so that it covers that part of the curves which most nearly approaches the ideal.

Fig. 6 gives the plate family for a typical output type of pentode. It will be noted that the almost horizontal portions of the curves are almost straight and parallel, but are not nearly equidistant for equal increments of grid voltage. For instance, on any load line that can be drawn on Fig. 6 through the solid-drawn curves, the distance intercepted by EQ is greater than that intercepted by QG. As before, this inequality represents distortion of the output, and a glance at Fig. 6 compared with Fig. 5 shows that more distortion is to be expected from a pentode than from a triode. In the pentode the actual load line is much more critical in terms of achieving minimum distortion than is the case with triodes. This is one of the great advantages which the latter possess. Wide variations in load resistance with a triode result in very slight changes in total distortion, almost the only effect of the variation being to alter the power output. With a pentode, however, large changes in load resistance cause large alterations in the amount of harmonic distortion produced, and the best load line to use is therefore fairly critical as compared with the triode case.

For this reason, somewhat more comprehensive estimation of distortion should be made in choosing the load line for a pentode or beam tube.

POWER OUTPUT

Since with pentodes considerable amounts of third harmonic are generated, the power output formula used for triodes gives rather less than the actual output, so that a better formula to use is given below. This formula entails the use of two new current values, Ix and Iy as well as I max and I min, which have the same meanings as before. Ix is the plate current corresponding to a grid voltage of 0.293Ec, where Ec is the quiescent grid bias as before and Iy is the plate current corresponding to a grid voltage of 1.707Ec. In order to carry out the estimation of Ix and Iy, it is necessary to make a guess at where the curves for these grid voltages would cut the load-line, because in general they will be odd values for which curves are not given. The formula for power output is

$$\text{Power output} = \frac{[\text{I max} - \text{I min} + 1.41\ (\text{Ix} - \text{Iy})]^2\text{Rl}}{32}$$

As for triodes, the resistance represented by the load-line is given by

$$\text{Rl} = \frac{1000\ (\text{E max} - \text{E min})}{\text{I max} - \text{I min}}\ \text{ohms}$$

where E max and E min are in volts, and I max and I min are in milliamps.

DISTORTION

From Fig. 6 it is possible to estimate both second and third harmonic distortion. The latter is unimportant in triode amplifiers, since only very small quantities are produced, but it is quite important with pentodes and beam tubes because it is frequently much greater than the amount of second harmonic produced at the same time. The following formulae for second and third harmonic estimation use I max, I min, Ix, Iy, and Iq, all referred to in Fig. 6

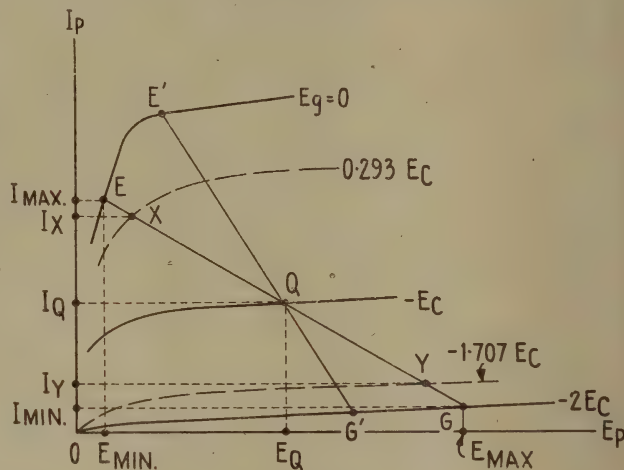

Fig. 6.

Per cent. 2nd Harmonic

$$= \frac{100\ (\text{I max} + \text{I min} - 2\text{Iq})}{\text{I max} - \text{I min} + 1.41\ (\text{Ix} - \text{Iy})}$$

Per cent. 3rd Harmonic

$$= \frac{100\ [\text{I max} - \text{I min} - 1.41\ (\text{Ix} - \text{Iy})]}{\text{I max} - \text{I min} + 1.41\ (\text{Ix} - \text{Iy})}$$

In choosing a load-line for pentodes, it is not desirable, as with triodes, to have a load resistance of about twice the plate resistance of the tube. This is because the pentode's plate resistance is very high (70,000 ohms and higher), and such a high load resistance would result in very high distortion. In general the load-line should not cut the Eg = O curve much below the sharp bend or "knee" in the curve, because in these regions the screen current becomes quite high, and under operating conditions the rated screen dissipation might be exceeded. With pentodes a load-line such as EG would be fairly satisfactory, as the ratio EQ/QG is fairly close to unity. This means, as with triodes, that the second harmonic distortion will be low. This is desirable for a single pentode output stage with inverse feedback, because the feedback reduces the distortion, either second or third, to a fairly low value, and a load-line like EG will give more power output for a given amount of distortion than would, say, E′G′. With this curve there is clearly a good deal of second harmonic, because EQ is noticeably different in length from QG′. Applying the ratio of E′Q/QG′ to the curve of Fig. 3, the 2nd harmonic distortion is found to be 14 per cent., which is rather high for any

purpose where high quality is required. However, a load-line approaching this one would be more satisfactory for push-pull operation, since the second harmonic is cancelled out in the output transformer with this connection. Thus it is good practice in push-pull pentode amplifiers to choose a load resistance which gives appreciable second harmonic and as little third as possible, because the latter is not cancelled out by the push-pull connection.

A MORE ACCURATE METHOD

Since pentodes are so prone to produce distortion if operated with an improper load resistance, it is often desirable to have a more accurate method of estimating harmonic percentages than the one given above. The "eleven ordinate" method fills this purpose admirably, as it is quite easy to carry out, though taking a little time to perform.

This method is exactly similar to the previous one, which is called the "five ordinate" method, and makes use of the plate current readings at 11 values of grid voltage instead of five. The first step is to draw the dynamic characteristic of the amplifier as shown in Fig. 7. This is nothing more than a curve of plate current against grid voltage taking the load into consideration. It is drawn by the simple process of reading actual plate current and grid voltage values off the characteristics as given in Fig. 6.

We will assume that the trial load-line has been chosen as EQG. First of all, two axes are set out on a piece of graph paper using convenient scales for plate current and grid voltage. The right-hand edge of the graph represents a grid voltage of zero, and the voltage scale is marked off in volts from right to left from 0 volts to a value of 2Ec. On Fig. 7 the minus signs have been used for the sake of accuracy of description, but these may be disregarded for the calculation.

The first point to be read off the load-line is G. The value of plate current at this point is read off and is plotted on the new graph against the grid voltage 2Ec. For example, the current might be 10 ma. when the grid is at its most negative voltage of — 24. Thus on the new curve the point is marked in representing 10 ma. and — 24 volts.

The next point to be read is the one where the next lowest grid-voltage curve cuts the load-line. For example, if the plate family has grid voltage curves every 4 volts, the next one would be that labelled — 20. So the process is continued until a point has been obtained for each grid-voltage curve on the plate family. When all points have been plotted, they are joined together in a smooth curve, as in Fig. 7. This curve is the dynamic characteristic.

It will be noted that no actual values have been given in Fig. 7, which is drawn in terms of Ec, the standing grid bias voltage. The grid swings over a range of voltage from 0 to — 2Ec, and the plate current varies from I max to I min in the process.

On Fig. 7, I max has been labelled I_0 and I min $I_{2\cdot0}$. Similarly, various other plate current values are marked in corresponding to a number of grid voltages, which are marked along the horizontal scale. To make this a little clearer, $I_{0\cdot2}$ means "the plate current when the grid voltage is 0.2 times Ec," and so on.

In a particular case such as the one we have been using as an example, Ec = 12v., so that E_1 = 12v., E_2 = 24v., E_0 = 0v., $E_{0\cdot7}$ = 8.4v., and so on.

The next step is to mark in the 11 points on the grid-voltage scale, and at each point thus marked to draw a perpendicular to cut the dynamic characteristic. At each point on the characteristic where one of these verticals cuts it, a horizontal line is drawn to cut the voltage scale as in Fig. 7. These points are then given the labels exactly as in Fig. 7.

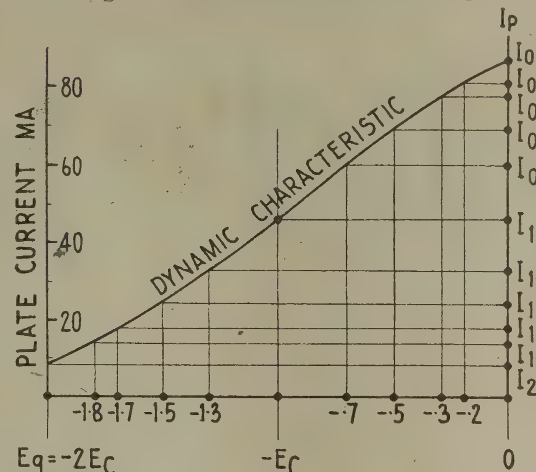

Fig. 7.

Now, all that has to be done is to take the appropriate formula, fill in the actual current values corresponding to I_0, $I_{0\cdot2}$, etc., and work out the arithmetic. It is important to note that the answer is in the form of **peak** plate current at the harmonic frequency, and not in harmonic percentage. In the formulae H_1 represents the fundamental peak plate current, H_2 the second harmonic current, and so on. When the fundamental has been worked out, the various harmonic percentages may be easily found by the formulae

$$\frac{100\,H_2}{H_1}\ ;\ \frac{100\,H_3}{H_1},\ \text{etc.}$$

for pecentage second, third, etc.

The power output **at the fundamental frequency only** is given by

$$\text{Power Output} = \tfrac{1}{2}H_1{}^2R1$$

The formulae for the various harmonics up to the fifth are:—

$$H_2 = \tfrac{1}{4}\,(I_0 + I_2 - 2I_1)$$
$$H_3 = 1/6\,(2I_{0\cdot5} + I_2 - I_0 - 2I_{1\cdot5})$$
$$H_4 = \tfrac{1}{8}\,(I_0 + 2I_1 + I_2 - 2I_{0\cdot3} - 2I_{1\cdot7})$$
$$H_5 = 1/10\,(2I_{0\cdot7} + I_0 + 2I_{1\cdot8} - 2I_{0\cdot2} - 2I_{1\cdot3} - I_2)$$
$$H_1 = \tfrac{1}{2}\,(I_0 - I_2) + H_3 - H_5$$

Although the eleven ordinate method just described takes a little time to perform, it gives quite an accurate idea of the performance that may be expected from a pentode or beam-tetrode stage, and is well worth while doing if published operating conditions do not coincide with the requirements of a particular application.

PUSH-PULL TRIODE AMPLIFIERS

The push-pull amplifier is not quite so easy to design graphically as the single-ended stage, if an

(Continued on page 48.)


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OUR GOSSIP COLUMN

Jack Kirk, who was recently appointed Auckland Representative for "Radio and Electronics," is an ex-Air Force navigator, with more than 2000 hours of wartime flying in his log-book. Before the war, Jack was well known in Auckland advertising circles, first as advertising manager of Macky, Logan, and Caldwell, Ltd., then as advertising manager of the Mirror Publishing Co., Ltd., and later as manager of the radio publicity firm of Radio Features, Ltd., thus gaining an all-round experience of publicity. Since his release from the Air Force, he has managed Walter J. Thompson's Studios, and now has realised an ambition to establish his own advertising service business. Jack will be devoting a good deal of time to our growing Auckland business, and we are confident that our clients will be given good attention. In addition, he will be pleased to write up any news item which readers may want passed on to us. Like everyone else these days, Jack Kirk has his office accommodation problem, and, pending a permanent address, he can be reached by telephone 45-356.

Left: Mr. John Rigg.
Right: Mr. Alan Clarke.

Mr. John Rigg, late Assistant to the New Zealand Trade Commissioner, Sydney, returned to New Zealand from Australia on 2nd June after resigning from the New Zealand Government service to take up the post as Manager of I.R.C., Ltd. Mr. Rigg has been absent from New Zealand for a period of ten years, and brings to the industry the wide experience that he has gathered overseas.

Mr. Alan R. Clarke has been associated with International Radio Company, Ltd., for many years, and is well known to the New Zealand electrical trade and radio business.

* * *

Amongst recent overseas visitors to Wellington was Mr. D. W. Rowed, chief chemist of Eveready (Australia) Pty., Ltd.

Mr. Rowed, who has spent some months in the States investigating latest developments in battery manufacture, broke his return flight to spend a few days with National Carbon Pty., Ltd., Wellington. Mr. Rowed, in discussing his visit to the States, said:

"The United States of America appears to have really got its teeth into the production of consumer goods. The electronics and radio industry is continuing to progress as a result of the tremendous war-time research and development effort, forming a very integral part.

"The National Carbon Company is meeting the dry-battery requirements of this very extensive industry, and its research and development have given high capacity to small dry batteries for miniaturised radio and hearing-aid equipment."

The dry battery has been, and will continue to be, a most essential part of our daily lives, and Mr. Rowed's visit to the United States of America ensures that New Zealand and Australia are fully informed on up-to-the-minute developments of this very important commodity, and the New Zealand radio trade will benefit by its developments.

Mr. Rowed left Wellington by air for Sydney, accompanied by Mr. R. D. Greenwood, managing-director of National Carbon Pty., Ltd., who will attend a production conference at the Eveready plant.

* * *

Roy Stevens, who used to be with Turnbull and Jones in Wellington before the war, is now outside representative for N.Z. Industries, Ltd., Auckland. This job should be no trouble to Mr. Stevens—in recent years he has gained very valuable experience overseas in the manufacture of electrical equipment, and as he has had practical experience in several wire factories in the United States, his knowledge should prove very helpful to clients of his new employers.

* * *

The old-established firm of S. E. Moe Co., Ltd., Queen Street, Auckland, has changed hands. The business is now being run by Radio Specialists, Ltd., and this firm will continue to market the well-known radio line "Silvertone," which was established as a popular make by S. E. Moe over a number of years. The policy of Radio Specialists is to extend the distribution of "Silvertone," and they will be pleased to hear from interested dealers in this regard. The two young men active in the formation of the new company are R. B. G. McCrea, formerly in the Air Force, and S. J. Murray, late chief petty officer in the Navy. This enterprise is welcome and good wishes for success are extended the partners in the new firm.

* * *

At the left is Mr. J. H. Prickett, General Manager of Standard Telephones and Cables Pty. Ltd., New Zealand, who left recently in the "Arawa" on the first stages of a world-wide business-trip, embracing the United Kingdom, the Continent and the United States.

Mr. Prickett expects to be away for approximately six months.

* * *

We are extremely pleased to see that the Hohner Electrical Co. has now become the Grover Electrical Co. We always did get these names mixed!

THE RADEL QRP TRANSMITTER

For some months we have been promising ourselves the pleasure of providing for new or would-be amateur transmitters the design of a small and inexpensive transmitter, easily constructed, yet capable of excellent performance. Here is the result of some work performed in our laboratory with such a transmitter in mind.

LOW POWER FOR BEGINNERS AND OTHERS

Too frequently does one find in literature devoted to amateur transmitting, over-simplified transmitter designs, poor both electrically and mechanically, and not really suitable for operation by newcomers to the amateur bands. With this in view, "Radio and Electronics" has designed a low-powered transmitter capable of excellent results, both on phone and C.W., and specially adapted to meet the needs of those with limited cash resources and limited experience in the building of transmitters.

This outfit should also be of interest to many who have been on the air for some time, and who have wanted to build a properly engineered job with rather more output, and much more suitable for amateur work than the ubiquitous ZC1's.

DESIGN FEATURES

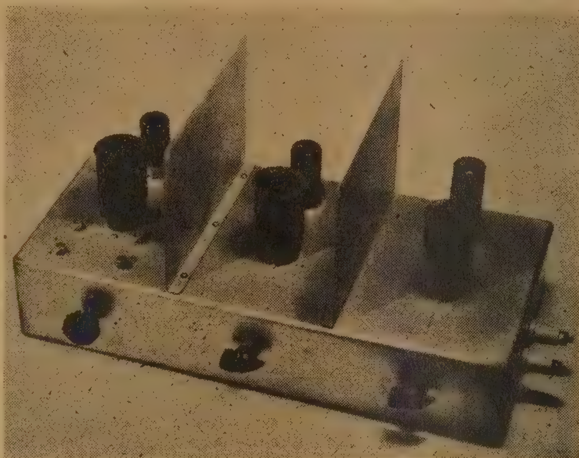
Extreme circuit simplicity has not been sought after, for we believe that there is no real reason why a small transmitter should appear as simple as a crystal set. In fact, there are a number of reasons why it should not, chief among them being that over-simplification leads to many troubles both of operation and performance.

What has been aimed at in this transmitter is ease of operation, together with a performance equal to that expected of costly high-powered transmitters. For example, in these hard times, a simple M.O.P.A. transmitter is not good enough, either in stability or in ease of operation, for a low power-output to be successful in gaining and holding a great number of contacts. A straight M.O.P.A. must needs be crystal-controlled, which in itself is a distinct disadvantage at times, owing to the congested state of the bands. Thus, we decided upon a line-up consisting of oscillator, doubler, and power-amplifier. This arrangement allows a self-excited oscillator to be used (together with its desirable frequency mobility) while giving ample stability for either phone or C.W. working.

A special oscillator circuit has been used which allows oscillator keying to be employed and gives a C.W. note hardly to be distinguished from that of a high-quality crystal-controlled job, keyed after the oscillator stage. Due to the very low oscillator power involved, key clicks and thumps are notably absent. The stability of the oscillator is such that when keyed in the cathode circuit, not the slightest chirp is in evidence, even though the screen is fed from a dropping resistor and not from a voltage divider.

V_2, the doubler stage, is used as such even on the 80m. band, in order to be able to run the oscillator at half the signal frequency at all times. This is a potent factor in realising the excellent frequency stability that has been achieved.

The power amplifier stage uses a 6V6 in a circuit which ensures that neutralisation is unnecessary. This is a great advantage, because receiver tubes such as this one usually require neutralisation in spite of being tetrodes, since the grid-plate capacity, though small enough to give no trouble if extreme shielding precautions are taken, is too large to leave unneutralised with the usual circuit arrangements possible when the plate and grid pins are both on the tube base. The grid is earthed and the excitation is applied to the cathode instead. With the grounded-



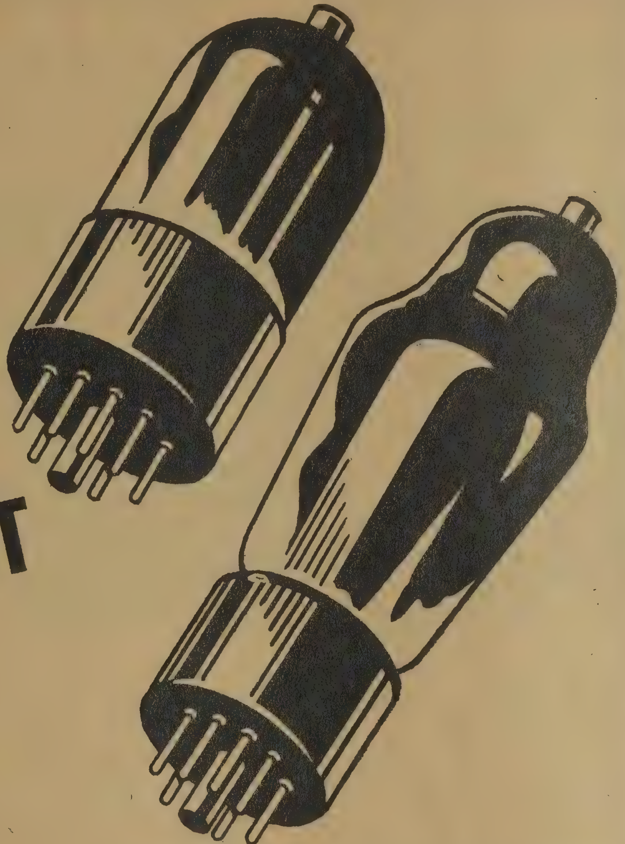
General view of the R.F. end. If the transmitter is rack-mounted, a front panel may be added, and a direct-reading dial attached to the oscillator tuning control which is at the left in the picture.

grid circuit, neutralisation is automatic, so that the scheme may be worked even with certain triodes. However, with tetrodes and pentodes, this connection virtually eliminates all chance of instability in the P.A. stage—a great advantage for the experienced and the newcomer alike.

The modulator is a single 6V6, and the transmitter is capable of 100 per cent. modulation. A modulation transformer is not used, this being replaced by the old Heising system, which uses a choke and resistor instead.

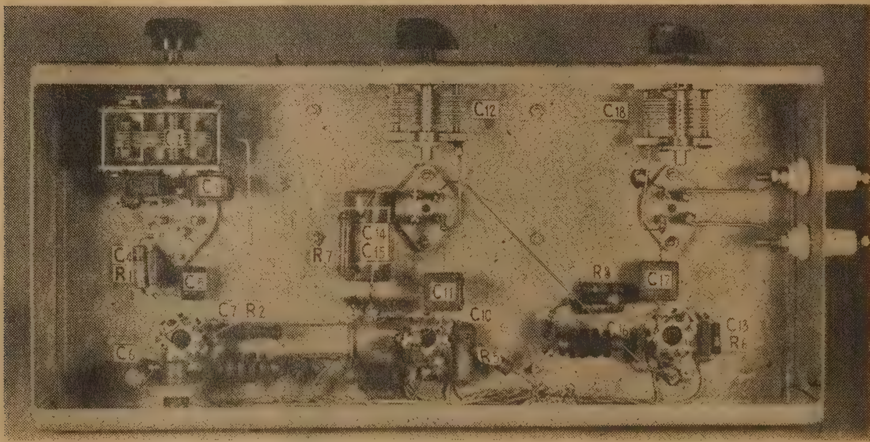
In a low-powered job like this one, there is no disadvantage at all in using this scheme. The linearity of modulation is equal to that realised with the modulation transformer, and as long as the P.A. is run at the correct plate current it presents a matched impedance to the modulator, and 100 per cent. modulation is achieved. This modulation circuit has the advantage of cheapness, too, since a 100 ma. modulation choke, which can be of the ordinary small smoothing variety, is a good deal less expensive than even a small modulation transformer—as well as being more efficient.

Enough gain has been given the speech amplifier to enable a crystal or dynamic microphone to be used,



or, if so desired, a small permanent magnet loudspeaker.

The power supply is simple, inexpensive, and straightforward, a single transformer of the 150 ma. receiver variety supplying filament and H.T. current for the whole transmitter.



Underneath view of the R.F. end of the transmitter, showing the placement of parts. The oscillator tube is at the left, together with its coil socket and tuning condenser. The cathode and plate chokes for V_1 may be seen close to the oscillator socket. The long bus-bar running diagonally is the lead from L_{11} to the cathode of the final amplifier. The stand-off insulators at the right are the output terminals. The power socket may be seen at the front of the picture between the sockets of the doubler and final amplifier.

All controls except those for tuning are located on the power-supply and modulator chassis, and comprise transmit-receive switch, phone-C.W. switch, key jack, microphone jack, and audio gain control. Provision is made for a meter, to be mounted on the modulator panel and to read the plate current of the final amplifier.

THE CIRCUIT IN DETAIL

(1) Oscillator:

The oscillator, V_1, is a 6SJ7 in an electron-coupled circuit, with one or two unusual features. First of all, the plate circuit is not tuned, the output being choke-capacity coupled to the grid of the doubler. This results in slightly less drive for the doubler than might be obtained by tuning the oscillator plate circuit, but this is unimportant, as the untuned coupling provides enough drive in any case.

The second point about the oscillator circuit is that the cathode is not directly connected to the grid coil, as is more usual. Instead, the cathode is kept above ground to R.F. potentials by means of the choke, L_2, and the cathode is connected to the grid-coil tap through a condenser, C_5. The condenser C_6 bypasses the choke to earth and enables a D.C. return lead to be taken via the connecting cable to J_2, the key jack. The advantage of this connection is in allowing the grid coil L_1 and the associated tuning condensers all to be grounded to the chassis, simplifying the mechanical mounting.

The third and final point about the oscillator circuit is that the grid is tapped down the tuned circuit. This gives the latter a higher Q,, and therefore increases the stability of the oscillator. L_2 is a 2.5 mH. R.F. choke, as are L_3, L_4, and L_6.

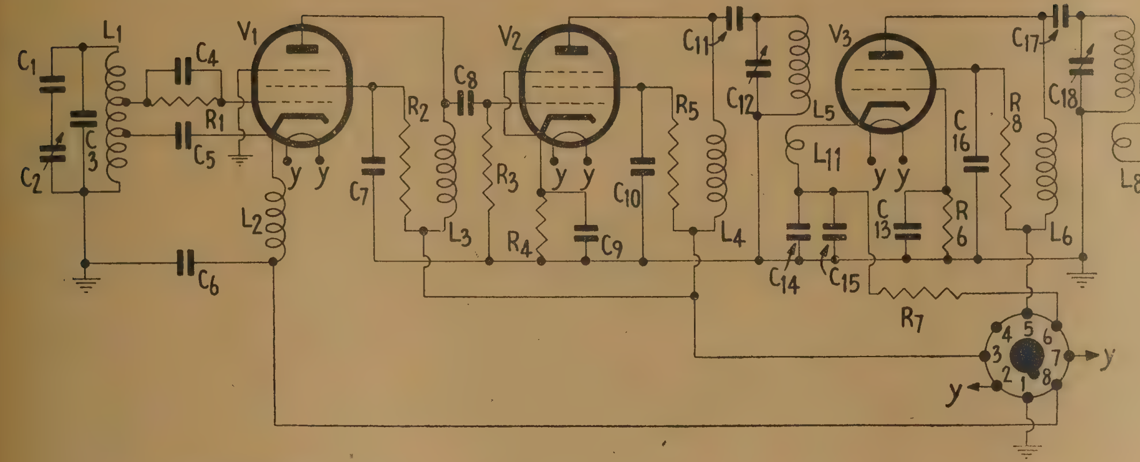
(2) Doubler and P.A. Stages:

The doubler stage is quite conventional except for using a 6AC7/1852. This tube is a little more expensive than the 6SJ7, but has been used here because it is definitely superior to the latter as a frequency multiplier, owing to its high mutual conductance. Cathode bias and grid-leak bias in conjunction are used with this tube, and hold the plate current down to a reasonable value under key-up conditions. Similarly, cathode bias is used on V_3, the P.A. stage. R_7 is the bias resistor, which is returned to earth through the plate milliammeter, which is connected at the modulator chassis. It is important to note the two bypass condensers C_{14} and C_{15}, used across R_7. The reason for this apparent duplication is that the 6V6 cathode must be bypassed for both R.F. and audio voltages. The high-capacity electrolytic, which is satisfactory for audio bypassing, is not relied upon to bypass R.F. satisfactorily, because its inductance would probably be too high to allow it to do this, so that a small mica condenser is placed in parallel with the electrolytic to ensure that bypassing is complete at both audio and radio frequencies.

The plate circuits of both doubler and P.A. are parallel fed with 2.5 mH. chokes, to enable the rotors of the tuning condensers C_{12} and C_{18} both to be earthed, and to remove D.C. from the coils, which may then be plugged in and out with the H.T. applied to the transmitter, with no danger of a shock.

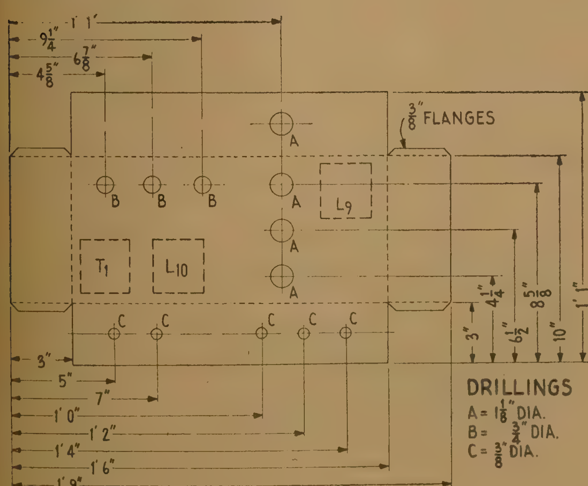
As was mentioned earlier, the grid of V_3 is earthed for R.F. voltages by the condenser C_{13}, but the grid-leak R_6 allows the grid current to produce some of the necessary grid bias in the usual way. As for V_2, the cathode bias resistor keeps the plate current of V_3 down when the excitation is removed. In fact, the whole R.F. end of the transmitter draws almost the same H.T. current whether the key is up or down. This is very helpful in that it increases the keying stability. The power supply regulation is not particularly good, since the filter is a condenser-input one, but since the current drain hardly varies during keying, regulation is not of much importance, even when the set is used for C.W .transmission. Apart from the cathode-input circuit, the P.A. stage is quite conventional. A series dropping resistor is used in the screen circuit in order to allow the stage to be fully modulated.

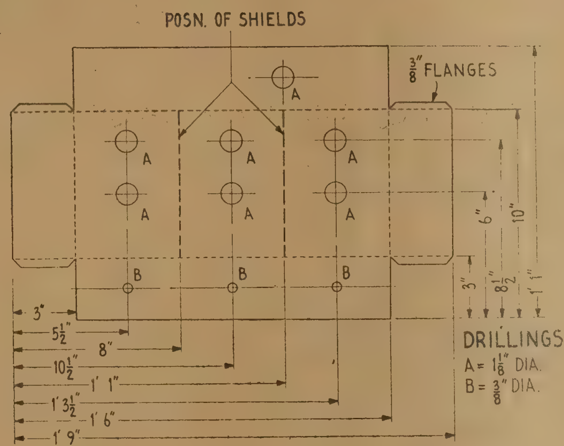
(To be continued.)



COMPONENT LIST

R_1, R_6 = 25k. 1w.
R_2, R_3, R_5 = 50k. 1w.
R_4 = 150 ohms.
R_7 = 250 ohms.
C_1 = 300 mmfd. mica.
C_2 = 150 mmfd. variable.
C_3 = 375 mmfd. mica.
C_4, C_8, C_{13}, C_{16} = 100 mmfd. mica.
C_5 = 500 mmfd. mica.
C_6 = 0.01 mfd. paper.
C_7, C_9, C_{10} = 0.02 paper.
C_{11}, C_{15}, C_{17} = 0.001 mica.
C_{12}, C_{18} = 100 mmfd. variable.
C_{14} = 25 mfd. 40v. electro.
Note: C_1 and C_3 should be made up if necessary of obtainable values in parallel.
L_2, L_3, L_4, L_6 = 2.5 mH. R.F. choke.
V_1 = 6SJ7 or 6AC7.
V_2 = 6AC7.
V_3 = 6V6.





Above: Working diagram of chassis for R.F. portion of transmitter. Bottom Left: Working drawing of chassis for power supply and modulator portion of transmitter.

Note: Both chassis are dimensioned so that it is possible to add a front panel of standard rack-and-panel width, so that the complete transmitter may be rack-mounted if desired.

COIL DATA FOR 80m. WORKING

All coils are wound with 22 S.W.G. enamelled wire on 1½ in. ribbed former.

Osc. Grid, L_1: 30 turns, 16 turns per inch, tapped at 8½ and and 25 turns from earthed end.
Doubler Plate, L_5: 28 turns, close-wound.
Final Grid, L_{11}: 15 turns, close-wound.
Final Plate, L_7: 29 turns, 16 turns per inch.
Aerial Coupling, L_8: 4 turns, 16 turns per inch.

THE SERVICE SECTION

PRACTICAL TROUBLE-SHOOTING—Part VII

By C. R. LESLIE, late Technical Officer, Royal Aircraft Establishment.

RECEIVER FAULTS (CONTINUED)

IV—DISTORTION

The word "distortion" really covers a multitude of sins, as it implies in its fullest sense, impure reproduction of the transmitted signal. The inclusion of unwanted frequencies from whatever source, such as "static," causes distortion of the reproduced waveform. In practice, however, it is usual to make a distinction between random transient frequencies and related or harmonic frequencies, the former being grouped under the heading of "noise" or "interference." Noise frequencies are commonly due to "static" or atmospheric electrical disturbance, "shot effect" emanating from the valves, "thermal agitation" due to erratic electron movement in the wiring and components, "parasitic oscillation" set up in any part of the circuit, aerial pick-up of sparking frequencies from motors, generators, and the like, and finally, a certain amount of "crackle" radiated from the transmitter.

Aerial crackle, shot effect, and thermal agitation are inherent defects which together form a limit to the sensitivity of a circuit, as no purpose is served in designing for a sensitivity such that the noise voltage exceeds the signal voltage.

Aerial pick-up of unwanted frequencies is often separately classed as "interference," and interference suppression is rapidly becoming a distinct science and field of research as well as the subject of special regulations, so is rather outside the field of the normal serviceman. Second channel interference is catered for by the set designer.

In this article we shall be mainly concerned with distortion resulting from faults developing in the receiver and which will be discussed under the two main headings of frequency and amplitude distortion and (for want of a better term) "harmonic noise." The latter will include microphony, speaker, and cabinet resonances. Random noises such as crackle will also be touched upon.

FREQUENCY DISTORTION

Frequency and amplitude distortion are both present in some degree in all receivers; it is only when they become excessive that they become intolerable, specially to the sensitive "musical ear." A third form, namely, phase distortion, is mainly of concern in television sets; the ear is not responsive to phase difference in moderate quantities, so we have no need to worry about it.

Frequency distortion is deliberately introduced to prevent whistles and sideband splash by keeping the upper limit of produced frequencies below 10 kcs. In practice, it is usual to restrict the response to about 8 kcs., because a sharp cut-off in the response curve cannot be expected. Midget-type superhets. are often limited to some 5 kcs., with a variable top-cut to some 3 kcs., which accounts for the drop in quality in many of these models as compared with their console cousins.

From a servicing point of view, we are more interested in either an abnormal loss of the higher or lower (bass) frequencies. The former can be caused by a shorted tone control resistor or by a change in capacity of an output valve's R.F. bypass condenser. The more usual defect lies in the loss of bass response, giving a thin, tinny reproduction and often accompanied by a loss in volume. An extreme case occurs when the coupling condenser C_1 of Fig. 1 is open circuited—strong stations may then be just audible, but very thin in quality. Again, if the cathode bypass condenser C_4 of the output stage loses capacity, the bass response will be attenuated, while an open circuit will also reduce the volume due to negative feedback to the grid.

Tone controls when inserted near the output end

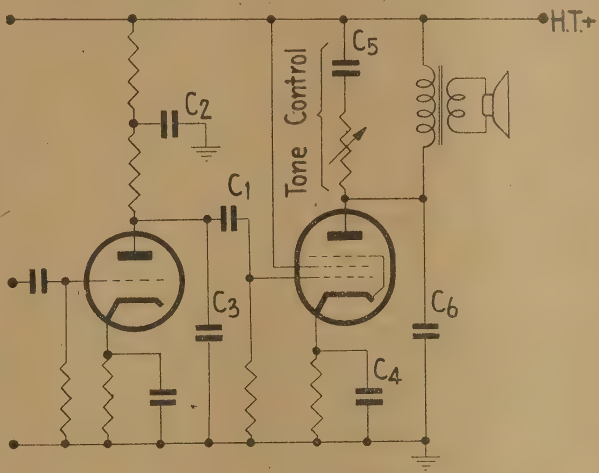


Fig. 1.

are responsible for great variation in volume because the signal amplitudes are high, and hence reduce the amplification by the amount of compensation. Ideally, they should be incorporated in the first L.F. stage of a two-stage amplifier plus power valve. Loss in volume is not frequency distortion, but these remarks have been added here to couple with the remarks in the preceding paragraph.

Another form of frequency distortion is experienced if the tuned circuits are too selective—that is, the response curve is sharply peaked. This leads to marked attenuation of frequencies only a few kcs. each side of resonance. To avoid this, the band-pass circuit and double-hump over-coupled I.F. transformers were introduced so as to obtain a reasonably level response over a band of some 10 kcs. wide each side of the resonant frequency. This is a point to watch out for when aligning receivers by ear or output meter. The frequencies used for reproduction are dependent on the transmitted matter—that is, for speech a band of 200-2500 c/s. is more or less standard practice, while for music the band may vary from 100-3000 c/s. or 30/15,000 c/s. It should be noted that the loss of frequencies above 3000 c/s. tends to change the timbre of the instruments so that a violin may

sound more like a flute, while for spech the sibilants become less pronounced.

As a rough guide, we may summarise the symptoms thus: The lack of high notes can be due to—

(1) Too sharply peaked R.F. and I.F. response curves.
(2) Shorted tone control resistor or change in capacity of the output R.F. bypass condenser, C_6, Fig. 1.
(3) Too large I.F. filter condensers, C_1, C_2, Fig. 2.
(4) Too large anode bypass condenser, C_3, Fig. 1.

Deficiency in bass response may be due to—

(1) The coupling condenser C_1 of Fig. 1 being too low in value, and in extreme cases to being actually open circuited.
(2) Loss in capacity of the cathode bypass condenser C_4 of the output valve.
(3) The time constant of the A.V.C. system may be too small, due to either a change in value of the resistors or of the decoupling condensers.

AMPLITUDE DISTORTION

Amplitude distortion commonly results from the overloading of a valve so as to encroach on the non-linear parts of the characteristic, and can be due to incorrect biasing or the falling-off in emission of an ageing valve. The name is given to the flattening of the waveform peaks either at the top or bottom, or both, and, as this introduces unwanted harmonics, it is really another form of frequency distortion, but the name is retained to serve as a distinction. The cure for such faults is obviously to correct the biasing with fresh components or replace old valves. Overloading may also occur if the A.V.C. is not functioning, the effect being most apparent on loud passages. The A.V.C. action may be checked by taking anode current readings of a controlled valve while injecting an unmodulated signal at the aerial terminal and gradually increasing the modulation of the signal generator. If the A.V.C. is functioning correctly, the meter reading should remain steady. Alternatively, the current readings may be taken when tuned to a strong station, though in this case the needle will give slight kicks with sudden fortissimo passages, but even in this case the change in anode current should not exceed some 5 per cent. of the standing current.

An intervalve L.F. transformer, and to a lesser degree the output transformer, may be the source of distortion, for if the iron core is easily saturated any increase in current will alter the inductance value and hence the anode load and valve output. For this reason, large cores are to be preferred.

The detector stage may produce amplitude distortion, even with the almost universal double diode. Since the small diode used in multiple valves will normally handle an input of some 50 volts quite comfortably, the input is not considered to be critical as long as it exceeds a certain minimum value so as to reach beyond the small initial bend of the characteristic. Considering the familiar circuit of Fig. 2, requirements for satisfactory operation are that the load impedance to modulation frequencies is high compared with the diode impedance and not greatly less than the D.C. resistance, while the load impedance at the carrier frequency must be small. The load impedance at low modulation frequencies is the D.C. resistance, and maximum linearity is obtained when this is high. At high modulation frequencies C_1 and C_2 act as shunts. C_1 must be small, as it is the carrier load impedance, and C_2 must be similar to C_1 to complete the filter correctly. R_2 is the volume control, and is effectively in parallel with the diode D.C. resistance as far as modulation frequencies are concerned, so that the A.C. impedance of the diode load circuit becomes less than the D.C. resistance, but if R_2 is some four times the diode D.C. resistance (comprising R_1 and R_1 the filter resistor of some 50,000 ohms value), distortionless rectification can be secured for 80 per cent. modulation. For this reason, some circuits are designed to incorporate the volume control as R_1 and to use a fixed resistor of some 10 megohms for R_2.

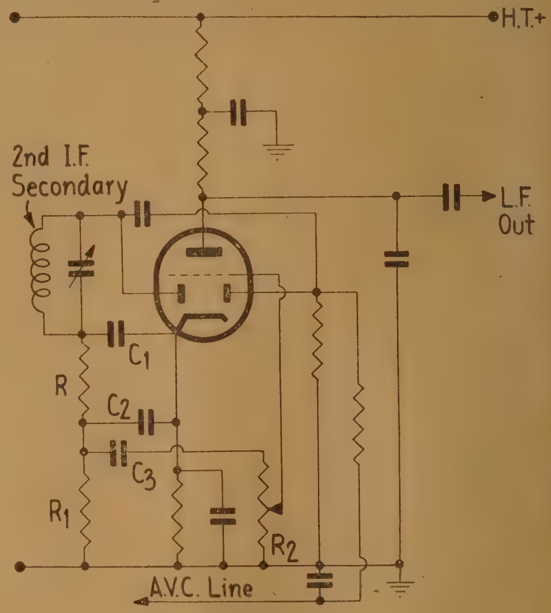


Fig. 2.

The circuit is reasonably fault-proof, but if R_2 decreases in value from age, moisture, or other causes then distortion will occur, a big drop in value causing severe distortion. A short-circuit between the slider and the upper end of the element will cause bad distortion at low volume. Open or short circuits in any of the components will also upset the operation, and, if the diode emission deteriorates, the characteristic will quickly bend over and leave only a comparatively short linear portion, so that anything exceeding a very moderate input will result in top cut of the waveform peaks. The characteristic of the A.V.C. diode will be similarly affected so that the amount of bias voltage available is limited to a low value, and the R.F. valves, especially the last I.F. valve, are likely to be overloaded on strong signals. If the set works satisfactorily on distant or weak stations but distorts badly on strong stations, the diode should be immediately suspect. If replacement does not effect a cure, then the A.V.C. decoupling resistors and condensers can be checked.

RECEIVER NOISES AND RESONANCES

The Loudspeaker

Apart from faults in the field winding, the loudspeaker is often the source of distortion very like that produced by an overloaded valve. The defect

is usually traceable to the cone suspension system. If loud passages appear blurred or "fuzzy," it is probably a sign that the speech coil movement is not free, due perhaps to dirt accumulating in the air gap. The only remedy is to remove the cone movement and thoroughly clean the core. Or again, the cone and speech coil may be off-centre, so that the coil former scrapes against the core, resulting in similar defective reproduction. The remedy is to re-centre the speech coil by loosening the cone spider lock screw and inserting paper shims round the soft iron core and then tightening the lock screw. Finally, the speech coil winding may have developed loose turns which impede the movement, in which case the cone must be removed and the winding readjusted and fixed with a thin coat of insulating varnish.

The paper cone will cause distortion if it is split or torn, due to the edges rubbing together. The only really satisfactory remedy is to replace the cone unit, but repairs may be effected by the careful use of thin tissue paper and a thin adhesive, or by the application of a thin strong glue on the torn edges themselves. In the latter case, if the tear is large and the glue sets hard, the chances are that spurious resonances will be set up to cause blurring at various points in the audible range.

Apart from the natural resonance of a speaker (which design usually makes at well below 100 c/s.), cabinet resonances have to be considered. The "infinite baffle" is the ideal to be aimed at, and in practice this is reasonably approached if the measurement from side to side across the front, taking the measurement from the rear edges of the two sides, is five times the diameter of the speaker cone mouth. A practical remedy to counteract cabinet resonance which gives a "woomphy" reproduction is to cover the back of the speaker with a felt cloth—which may, of course, be conveniently found as a lady's discarded hat—or, if design permits to glue in wood panels in such a way as to break up and disperse air vibrations, using trial-and-error methods.

MICROPHONY

The name is given to a low-pitched howl which usually builds up slowly till the volume swamps the reproduction. Sometimes the howl is started by a loud passage of music or a sudden jar on a floor board under the set. Again, in some cases the howl will remain consistently at a medium level and appear as ordinary bad mains hum.

The two main sources of this complaint are the valves and tuning condenser. A faulty valve may be traced by tapping each one, especially the predetector tubes, when the receiver is operating but with the howl quiescent, until a valve is reached that starts the howl or produces a "pong" sound. Alternatively, it may be traced when the howl is present by holding each valve firmly in turn until the noise ceases or considerably diminishes. The best remedy is to replace the valve, but where this is not possible a temporary cure can be effected by wrapping cotton wool round the valve with rubber bands or insulating tape, or some such similar arrangement to prevent speaker vibrations from penetrating through the glass envelope to the internal structure.

The trouble is more usual with older designs; the modern trend is to dome the envelope, and in this dome place a mica disc to anchor the top ends of the grid supports and so minimise the chance of

internal vibration being set up. With midgets, the supports are much shorter and less prone to vibration.

Microphony from the tuning condenser is catered for by the rubber suspension of the frame, with perhaps the addition of rubber supports for the chassis. The cause of condenser microphony is the same—namely, air vibrations from the speaker which set up vibrations in the condenser vanes and thus cause an oscillatory change in capacity, with resulting "wobbling" of the I.F. The remedy is to check up on the rubber mountings and replace them if they are hard or perished.

MISCELLANEOUS NOISES

This is a subject that can only be treated in a very general way in the space available, but in every case it is a question of the generation of unwanted voltages, and these must be searched for in the light of the actual symptoms produced and practical experience. It should be remembered that any single symptom may be the result of a combination of unwanted voltages, so that two similar noise voltages of values M and N will combine to produce a noise voltage equal to

$$\sqrt{M^2 + N^2}$$

proportional to the band-width.

Taking crackles first—the commonest cause is a lose connection, which should not be difficult to trace amongst the wires, screen-can nuts, and parted strands in stranded leads, not overloking dry or "rosin" joints. Internal breaks in carbon resistors also cause crackles when the set warms up, especially in grid leaks. Dirty valve sockets and switches, leaky condensers with perforated dielectrics, foreign matter accumulated in the tuning condenser vanes, all can add their quota.

Loud and persistent hissing may be remedied by replacement of the R.F. and mixer valves, as most of it originates in this portion of the circuit. The frequency changer is usually the worst offender, because hiss will be abnormal if the mixing ratio of signal and oscillator voltages is incorrect. If a change of valve has no effect, the oscillator circuit should be checked in detail for faulty components and connections.

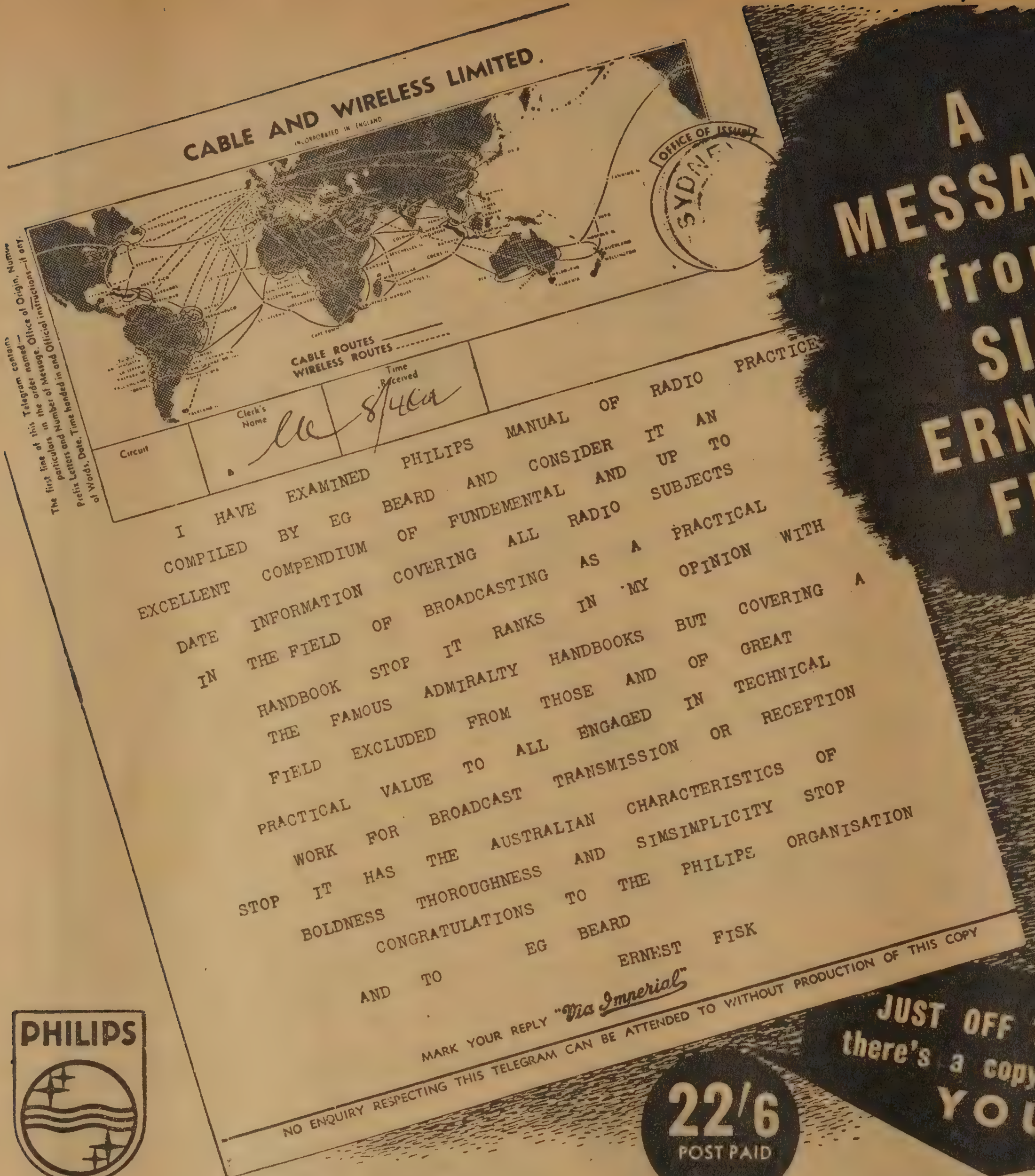
PARASITIC OSCILLATION

This is another general fault that is often most difficult to track down, as it can occur at so many points and is also often the unsuspected source of much of the background noise and hiss. It can occur in the R.F. or I.F. stages, but is most likely in the oscillator. Grid stopper resistors may cure the trouble, and if it is in the oscillator stage a series resistor of a few hundred ohms (the best value being found by trial) connected between the coil and the grid should affect a cure. A check can be made by inserting a 1 ma. meter between the oscillator grid leak and cathode. The grid current with a 50,000 ohm resistor will be of the order of .1 — .5 ma. The tuning condenser is then rotated slowly through its full travel from minimum to maximum capacity. A slight tailing-off of the current can be expected as the maximum end is approached, as it is not practicable to keep the oscillation amplitude quite constant over the whole waveband, but the decrease should be smooth and gradual; if a sudden kick is observed, either up or down, parasitic oscillation is a certainty. Oscillator grid coils are often wound with resistance wire as a precaution against this defect, and a high resistance reading of this winding does not, therefore, indicate a faulty coil or connection.

Parasitic oscillation is also likely to occur in power stages, especially if push-pull circuits are used, grid stoper resistors of some 100,000 ohms will usually effect a cure. Where it occurs with a single valve, it is usually due to the use of a valve with a high mutual conductance and the most effective remedy is to introduce an element of negative feedback. In either case the oscillation is a supersonic frequency, but it beats with signal frequencies to produce comparatively low-pitched howls.

Finally, one usually unsuspected source may be found where two condensers are connected in parallel and joined to earth, the wires form an inductance loop, and the capacity for oscillation being the series connection, resulting in a resonant frequency of some 15-30 mc/sec.

A MESSAGE from SIR ERNEST FISK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I HAVE EXAMINED PHILIPS MANUAL OF RADIO PRACTICE COMPILED BY EG BEARD AND CONSIDER IT AN EXCELLENT COMPENDIUM OF FUNDEMENTAL AND UP TO DATE INFORMATION COVERING ALL RADIO SUBJECTS IN THE FIELD OF BROADCASTING AS A PRACTICAL HANDBOOK STOP IT RANKS IN MY OPINION WITH THE FAMOUS ADMIRALTY HANDBOOKS BUT COVERING A FIELD EXCLUDED FROM THOSE AND OF GREAT PRACTICAL VALUE TO ALL ENGAGED IN TECHNICAL WORK FOR BROADCAST TRANSMISSION OR RECEPTION STOP IT HAS THE AUSTRALIAN CHARACTERISTICS OF BOLDNESS THOROUGHNESS AND SIMSIMPLICITY STOP CONGRATULATIONS TO THE PHILIPS ORGANISATION AND TO EG BEARD

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FOR THE SERVICEMAN

List of Intermediate Frequencies used in Philips Radioplayers

Model	Year	I.F. Frequency
5V:5H:6V	1934	175 Kc/s.
588	1935	115 Kc/s.
522	"	115 Kc/s.
666A, S, D	"	256/285 Kc/s.
66B	"	465 Kc/s.
531	"	115 Kc/s.
335	"	475 Kc/s.
22B	"	456 Kc/s.
62B	"	456 Kc/s.
342	1936	475 Kc/s.
51B	"	456 Kc/s.
636	"	456 Kc/s.
516	"	465 Kc/s.
343	1937	475 Kc/s.
339	"	475 Kc/s.
626	"	456 Kc/s.
842	"	475 Kc/s.
351	"	475 Kc/s.
352	"	475 Kc/s.
355	"	475 Kc/s.
356	"	475 Kc/s.
6517	"	462.5 Kc/s.
72B	"	456 Kc/s.
82B	"	456 Kc/s.
715	"	470 Kc/s.
V7A	"	128 Kc/s.
247	1938	128 Kc/s.
248	"	128 Kc/s.
361	"	475 Kc/s.
362	"	475 Kc/s.
771	"	475 Kc/s.
462	"	475 Kc/s.
463	"	475 Kc/s.
862	"	475 Kc/s.
470	1939	128 Kc/s.
650	"	470 Kc/s.
660	"	470 Kc/s.
702	"	128 Kc/s.
753	"	470 Kc/s.
518	"	472.5 Kc/s.
528	"	472.5 Kc/s.
628	"	472.5 Kc/s.
541	"	472.5 Kc/s.
642	"	472.5 Kc/s.
152/155	1940	472.5 Kc/s.
153	"	472.5 Kc/s.
252	1941	472.5 Kc/s.
042	1942	472.5 Kc/s.
253	"	472.5 Kc/s.
773	"	472.5 Kc/s.
644	"	472.5 Kc/s.
157	1943	454 Kc/s.
158	"	454 Kc/s.
593	1946	455 Kc/s.
540	"	455 Kc/s.
594	"	455 Kc/s.
596	"	455 Kc/s.
598	"	455 Kc/s.
600	"	455 Kc/s.
546	"	455 Kc/s.

TRADE WINDS

SHOP WINDOWS—YOUR BEST SALESMEN

Versatile Ted Reid, of Eclipse Radio, Dunedin, is specialising in radio retailing with particular reference to "hams" and home constructors. The above photograph illustrates that Eclipse Radio is well aware of the large amateur builders' market in New Zealand, and by these attractive window displays the progressive ideals of the firm can be judged.

* * *

A recent change of name registered is that of the Hohner Electrical Co., Wellington, to the Grover Electrical Co. This does not involve any change in managership, but, as Mr. Grover was the founder of the organisation, it is fitting that his name should be associated with the title of the firm.

Very well established in the radio industry, the Grover Electrical Co. has plans ahead for an extensive sales programme, and has reported that new sales appointments are to be announced shortly.

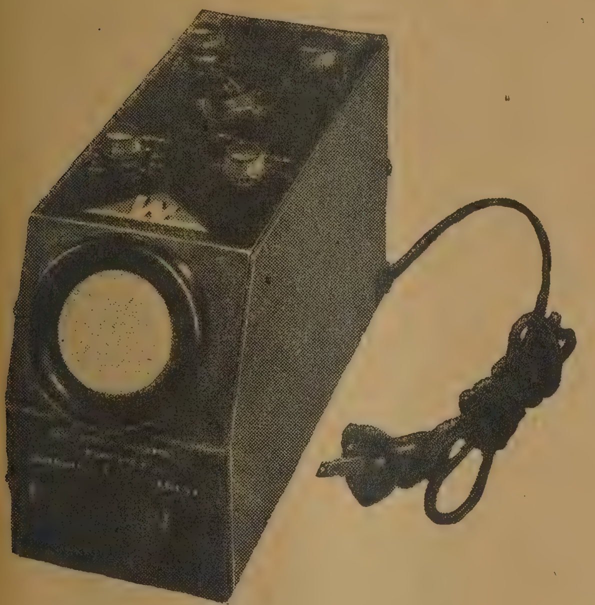
To Mr. and Mrs. Grover (Mrs. Grover is also an active member of the company) go the best wishes of the industry for the future.

* * *

Dominion Radio and Electrical Corp., Newmarket, Auckland, are in process of a large-scale reorganisation of their factory. More space has been found for their expanding radio assembly section by the not-so-simple expedient (these days) of moving their store to another building in St. Mark's Road, adjacent to the main premises fronting on Broadway. This has enabled the whole of the radio assembly to be brought within one huge room. This move, in turn, has relieved the space problem for electrical assembly. On the ground floor more space has been secured for the machine section. New equipment in the design room includes a Cossor double-trace oscilloscope. There has also been a renovation of staff amenities and the finishing touches are now being put to a fine new lunch room.

NEW PRODUCTS: LATEST RELEASES IN ELECTRONIC EQUIPMENT

THE NEW WATERMAN POCKETSCOPE
Model S-10-A



The Model S-10-A Pocketscope is a small, compact, lightweight instrument for the observation of repetitive electrical circuit phenomena. The Pocketscope is a complete cathode ray oscilloscope incorporating the cathode ray tube, vertical and horizontal amplifier, linear time base oscillator, synchronisation means and self-container power supply.

The instrument is capable of indicating in two independent dimensions—vertical and horizontal. As used normally, the vertical dimension is amplitude, and the horizontal may be either amplitude or time. However, by means of external signals, any variable time can be assigned to independent dimensions. Although it has practically unlimited application, some of its common uses include study of wave shapes, measurements of modulation frequency, phase shift, voltages, power, distortion-adjustments of audio amplifiers, radio, television, and F.M. receivers and transmitters, as well as any other apparatus producing electrical waves, tracings of vacuum tube characteristics, hysteresis, and other curves.

The Pocketscope weighs only 5¾ lb. and occupies less than .15 cubic feet of space. The cathode ray tube is magnetically shielded and the telescoping light shield (1 inch) permits observation even in places of high light intensity. The angle of vision is great. The construction of the Pocketscope permits its physical use on the floor, on the bench, or in any position convenient to the operator without diminishing the wide angle of vision.

The controls and terminals are placed functionally so as to permit easy adjustments without reference to complicated instruction. No re-connections are required for signal passing either through the amplifier or directly to the deflecting plates.

The vacuum tubes used are the famous miniature glass tubes that have proven to be superior in many respects to regular metal or glass tubes.

The time base oscillator uses a double triode tube connected as a multi-vibrator, producing a substantial linear trace from 10 cycles to 50 kc. Synchronisation with low voltages is possible in the audio, supersonic, and low R.F. ranges.

The response of the vertical and horizontal amplifiers is within 0 to —2 db. from 20 cycles to 100 kc. and is within —6 db. to 200 kc. Any variation from 1 kc. is downward, thus there are no positive slopes that produce non-linear phase shift.

TECHNICAL DATA

Power supply: Input 220 volts.

Operating Data:

	Amplifiers with gain max.	Direct connection to deflection plates
Vertical deflection sensitivity	*1v. RMS/inch	*30v. RMS/inch
Horizontal deflection sensitivity ..	*1v. RMS/inch	*24v. RMS/inch
Fidelity	*—2 db. from 20 cycles to 100 kc.	Depends upon external connections
Input resistance ..	.5 megohms	.5 megohms
Input shunt capacitance	36 mmf.	36 mmf.
Input series capacitance	.1 mf. 600v.	.1 mf. 600v.
Polarity of deflection	Positive direction is up for vertical input and to left for horizontal input	Positive direction is down for vertical input and to right for horizontal input
Time base oscillater	10 cyles to 50 kc. with sweep from left to right	

*Approximate values; factory standards excel these values.

Tube Complement:

6AU6 Vertical amplifier.
6J6 Time base oscillator and horizontal amplifier.
6X4 Power rectifier.
2AP1A Cathode ray tube.

Overall Dimensions:

Height, 6⅜ inches; depth, 10 inches; width, 4 inches; weight, 5¾ lb.

Terminals:

Two-pin jacks for vertical input.
Two-pin jacks for horizontal/sync. input.

CONTROLS
(from left to right and top, down)

Gain: Vertical gain and switch for direct connection to deflecting plates.

Gain/sync.: Horizontal gain or sync. adjustment and switch for direct connection to horizontal deflecting plates.

Range: Range switch having five positions for selecting time base range: 10-60 cycles, 60-300 cycles, 300-2000 cycles, 2m.-10m. cycles, 10m.-50m. cycles.

Frequency: Frequency control for selecting particular time base frequency in each range. Minimum frequency on left, or counter-clockwise, and maximum frequency on right, or clockwise.

Function: Function selector switch for selecting type of synchronisation or horizontal amplifier. This

switch has four positions:

EXT .... External sync.
LINE .... Power line sync.
INT .... Internal sync.
HOR .... Horizontal amplifier

Intensity: Intensity control with "on-off" switch for power. Rotation to left (or counter-clockwise) reduces, and to right increases intensity.

Focus: Focus control for controlling the line width.

Further details may be obtained from the New Zealand agents, Messrs. Turnbull and Jones, Ltd., Auckland, Wellington, Christchurch, Dunedin, Hamilton, and Palmerston North.

THE SOUNDMIRROR

The "Soundmirror" magnetic ribbon recorder now available in New Zealand is something really new in recording. On account of its versatility in amateur and commercial applications, it is anticipated that the "Soundmirror" will meet with an excellent sales response.

Sound is recorded on a coated magnetic ribbon, and a recording of 30 minutes' duration may be obtained on one reel of ribbon.

The frequency response is 100 to 5000 c/sec. $\pm$ 3 db. at full output. The signal-to-noise ratio is at least 40 db. Recordings may be made from microphone, radio, or pick-up inputs.

The number of playbacks which can be made is indefinite, and likewise, after erasure, the number of times the ribbon may be used for new recordings is also indefinite. At the press of a button, symphonies, jazz, operas, speeches, comedy, or any radio programme can be recorded.

Friends can be entertained with "home talent" recordings easily made with the handy "Soundmirror" microphone.

In the professional and commercial worlds, the "Soundmirror" will be invaluable in recording entire business or sales conferences, and dictation. To doctors, attorneys, and teachers, the "Soundmirror" means a new future for case history study and recorded observations. Recordings are easy to erase—or file away for a permanent record.

Further details about this versatile instrument may be obtained from the New Zealand agents, Messrs. Giles and Elliott, Wellington.

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"SPIN HEX" SOCKET WRENCHES

Radio and electrical servicemen will welcome the "Spin Hex" spintite socket wrenches, which are indispensable in an electronic workshop. The handles are constructed of amberyl, which is shock-proof, rugged, and an excellent insulator. The sockets will fit most of the nuts encountered in radio and electrical work. Two kits will be available—one will comprise five spintites complete with a steel bench stand, and the other is a leatherette roll comprising five spintites, three screwdriver blades, aligning tool, and two pairs of pliers. Orders may be placed with the New Zealand agents, Messrs. Swan Electric Co., Ltd., Auckland, Wellington, and Christchurch.

THE SYNCHRODYNE

(Continued from page 15.)

the advantages of a double-shift superhet. without any second I.F. channel being used! The high I.F. would give freedom from image interference, while the synchrodyne would give very high adjacent-channel selectivity.

No doubt more possible applications could be devised for this interesting circuit, but the above seem to be enough for a start, and we hope will lead to much useful experimental work.

QUESTIONS AND ANSWERS

(Continued from page 22.)

250 mmfd. only, so that if a number of each size is procured, it is possible to obtain any value by making suitable series or series-parallel arrangements of condensers, to use as each series condenser. The use of variable trimmers is not recommended, as this will enable the tracking of the receiver to be put out, but if fixed condensers are used there will be no effect on the tracking.

The 40m. band may create more of a problem, because in this case the required frequency range of 7 to 7.3 mc/sec. does not lie right at the high-frequency end of the band.

If full bandspread is required on 40m., it will be necessary to use fixed condensers in parallel with the coils for this band, as well as in series with the gang sections. A suggested trial value is 50 mmfd. in parallel with the coils, and 50 mmfd. in series with the gang sections. The method of testing whether the required values are in use is to wire in both series and parallel condensers, and turn the gang to minimum capacity. If the receiver frequency is now higher than 7.3 mc/sec., more parallel capacity must be inserted until this frequency is on the dial, but as close to the unmeshed position of the condensers as possible. When this has been attained, all that is necessary is to adjust the series condensers until 7.0 mc/sec. comes as close as possible to the fully-meshed position of the condensers.

If at the first trial 7.3 mc/sec. comes on the dial, but with the condenser gang too fully closed, the parallel capacities should be decreased.

In making these adjustments, it is highly important not to touch the alignment of the receiver, or the results will not be capable of interpretation. Once the right condensers have been chosen and permanently installed, then and then only is it advisable to touch the original pre-set adjustments for trimming and padding, and on the whole these are much better left severely alone in the positions which gave correct tracking before bandspreading is attempted.

ELECTRONIC MUSIC

(Continued from page 7.)

semitones within an octave are derived from one disc, cylinder or other rotor, each successive shaft will need to be driven at twice the speed of that providing the frequencies of the octave below, and gear ratios are then quite simple. The accuracy of the musical pitch will depend on the number of scanning elements or pick-up poles for the provision of each semi-tone. Constancy of rotational speed can be maintained within close limits by the use of synchronous motors, as the variation in mains frequency is normally small. The addition of some form of mechanical filter may be found to be necessary to maintain absolute constancy. Back-lash in the gearing must be eliminated as far as possible for obvious reasons, and care must be taken to avoid the creation of any microphonic noise from small relative movements in the generator components.

It is hoped that these few and very brief remarks will give some conception of the nature of the work associated in this really interesting field—one that can give the enthusiast a great many hours of absorbing occupation and one that offers so many entertaining problems for solution. The subject is sufficiently unexploited to be refreshingly new.

VALVE CURVES IN CLASS A AMPLIFIER DESIGN

(Continued from page 27.)

accurate analysis is performed. It is hoped at a later date to publish a separate article on the graphical design of push-pull amplifiers, since the subject is too wide a one to include fully in this present series.

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